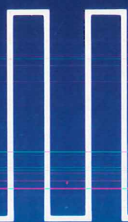


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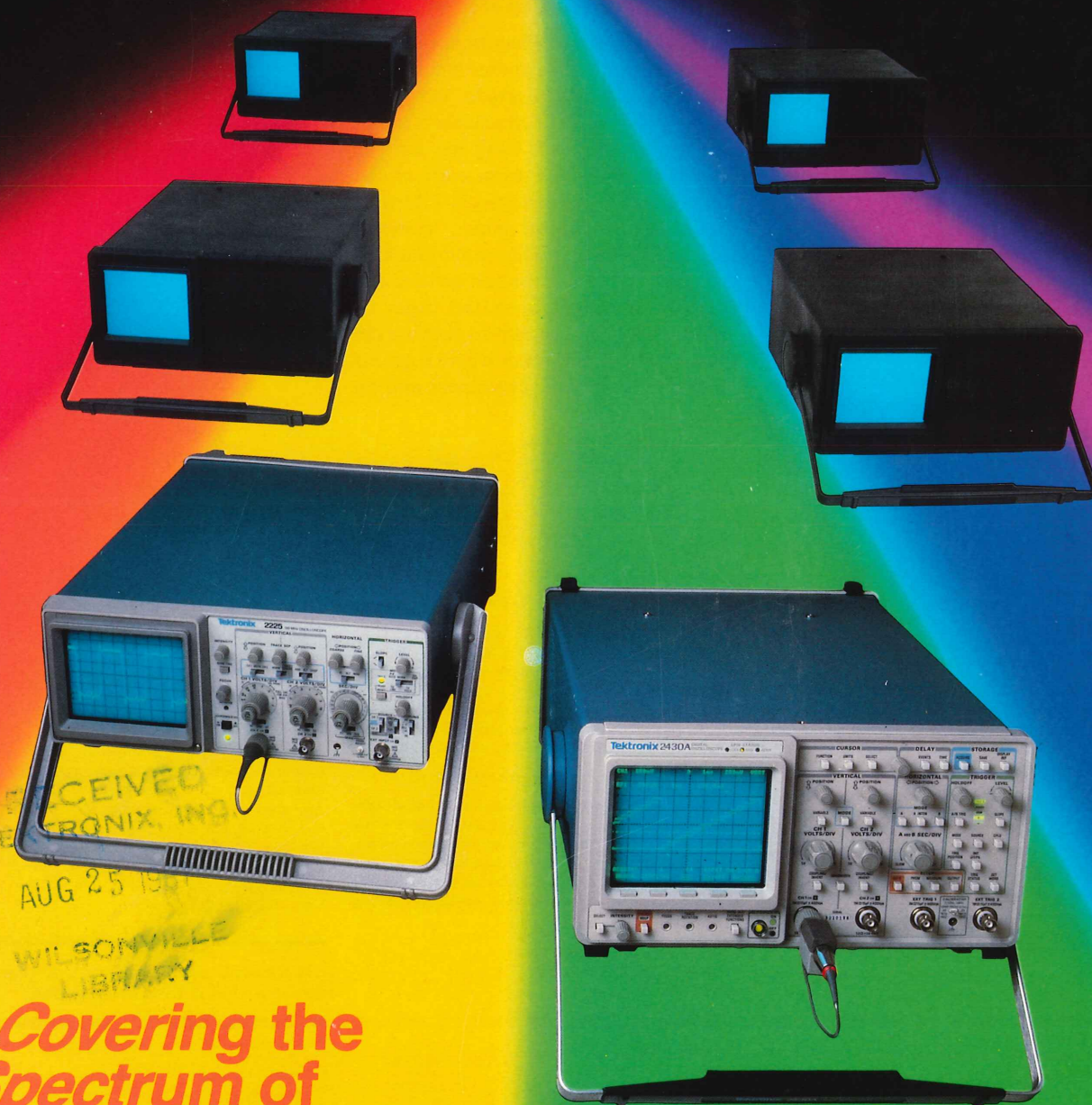
APPLICATION
INFORMATION

VOL. 12 NO. 2
SUMMER 1987



HANDSHAKE

NEWSLETTER OF INSTRUMENTATION AND INSTRUMENT SYSTEMS



*Covering the
Spectrum of
Portable Measurements*

Tektronix®
COMMITTED TO EXCELLENCE

Art Anderson — Sales Engineer, Writer, Friend

Art Anderson began his career at Tektronix as a Sales Engineer over 30 years ago — some of you may have known him as your Tek representative in the Baltimore, Rockville (MD), and Cherry Hill Field Offices.

In 1970 Art transferred to Beaverton and served in a variety of roles, many of them related to writing and publications. He was widely known and respected throughout the company for his grasp of technical subjects and his ability to translate them into laymen's language.

After his recent retirement following 30 years service at Tektronix, Art continued to write for a variety of Tek groups on a free-lance basis. Only recently, he began editing some articles for future publication in **HANDSHAKE** — the first of these articles, **Network and impedance analysis with the 2430**, appears in this issue. Plans were being made to work closely with Art on future issues of **HANDSHAKE**.

But this was not to be. On July 12, Art was killed in a climbing accident on Mount Hood. His death leaves a large void because of his professional abilities. But it leaves even a larger void as a friend. We'll miss you Art!



Handshake updated

After 12 years we've updated the symbol which has "sealed" each **HANDSHAKE** article. Some of you noticed and commented on the new design first used in the last issue. For those of you who didn't notice, take a closer look at the enlarged view of our handshake shown below.

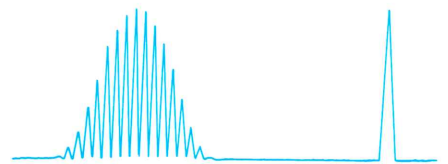
Besides a more open, cleaner design which is easier to print, you'll notice that one of the hands is definitely that of a woman. In today's business world, women are playing an ever increasing and more important role and we've attempted to reflect this in our symbol.

As you look at the handshake symbol below and each time you see it at the end of a **HANDSHAKE** article, remember that it's our "seal" of commitment to serving you — not only from the staff of **HANDSHAKE**, but from each of the more than 17,000 employees at Tektronix who take seriously our motto, "committed to excellence." This commitment is not only to provide the best articles and product information on the pages of **HANDSHAKE**, but also to provide the best products and service where it counts the most — in your instrument and on your job.




Oops!

Figure 8 in the article on the RTD 710 in the last issue (see **The RTD 710 — state-of-the-art in high-resolution digitizing** — Spring 1987 **HANDSHAKE**, page 4), showed a waveform to demonstrate the TV option using a 2T and modulated 20T pulse. This is a standard test pulse used in Europe to verify television performance. Unfortunately, we printed the waveform incorrectly — it was swapped end-for-end. The picture below shows the correct format for this pulse. Our apologies to our European readers who may have been confused by the waveform as printed originally.



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A look inside

Tektronix offers a full spectrum of portable oscilloscopes — the most complete lineup in the industry. In this issue, we introduce two new portables that “anchor” each end of this spectrum — the low-cost 2225 50 MHz Oscilloscope and the high-performance 2430A Digital Oscilloscope.

The feature article, **The 2430A — full measurement automation in a portable digital oscilloscope** describes the performance features by which this new instrument from the Portable Instruments Division revolutionizes digital measurements. You’ll find this article of particular interest if you’re looking for a portable instrument with built-in automatic measurement features.

Establishing new standards for low-cost oscilloscopes, the 2225, as described in the article **Tek goes under \$1000 with new portable scope**, brings features to low-cost oscilloscopes previously only available on instruments at many times the price. This instrument offered by the Portable Test Instruments Division warrants your attention for low-cost solutions to today’s test needs.

Last issue we introduced the 7912HB Programmable Transient Digitizer. In the article **The 7A29P — programmable high-bandwidth amplifier for the 7912HB and the 7912AD** we introduce the perfect companion for the 7912HB — a vertical amplifier plug-in which allows performance to 750 MHz with full vertical programmability.

For our focus on applications, we bring you **Network and impedance analysis with the 2430**. The program described in this article allows you to perform many of the functions of dedicated analyzers at a fraction of the cost.

In a new section called **Technology Update**, which we would like to make a regular feature of **HANDSHAKE**, you’ll find a tutorial on the GPIB and designing systems based on this interface — **Putting GPIB systems to work on everyday test needs**.

We’ve included a lot of information in this issue to help solve your measurement problems. For more information on any of the products described, or for help with other signal measurement needs, contact your local Tektronix Field Office or Tektronix Sales Representative for your country. And be sure to tell them you saw it in **HANDSHAKE**.

A. Dale Aufrecht
HANDSHAKE Editor

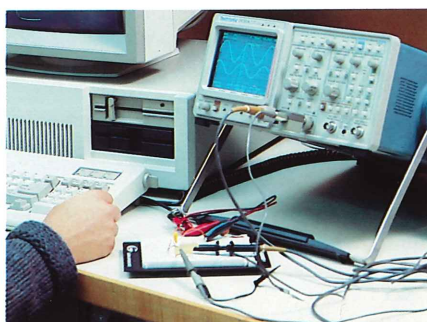
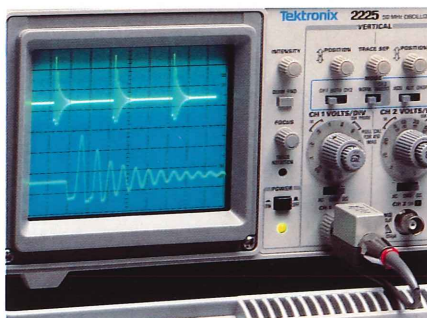
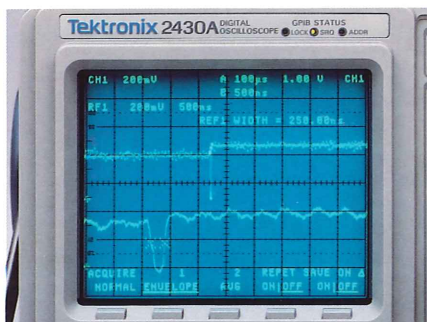
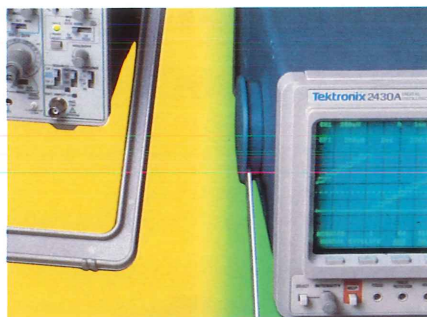


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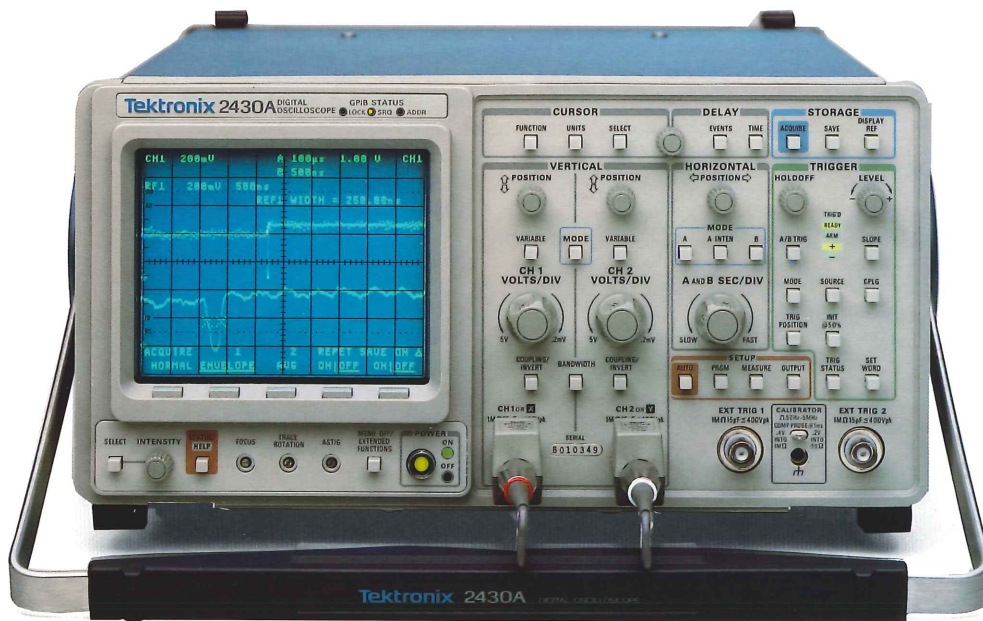
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The 2430A — full measurement automation in a portable digital oscilloscope

Joe Campos
DSO Product Marketing Manager
Portable Instruments Division
Tektronix, Inc.



Built-in setup automation and signal processing establish a new standard of measurement capability and simplicity in the portable, go-anywhere 2430A Digital Oscilloscope.

Today, portable oscilloscopes are a lot more than just oscilloscopes. The new 2430A Digital Oscilloscope from Tektronix is a case in point.

The 2430A is called a "digital oscilloscope" because everything is totally under digital control. This has some powerful implications in a systems environment. But the most powerful implications are in general day-to-day measurements, whether on the manufacturing floor, the design bench, or in the research lab.

For example, consider the 2430A display shown in Figure 1. Twenty waveform parameters are shown here. All are displayed on the 2430A screen in a "snapshot" measurement mode.

To make and record all 20 of these measurements using a conventional oscilloscope could take an hour or more. But with the 2430A, complete scope setup and the 20-measurement display can be completed by simply pressing three buttons — Auto, Measure, and Snapshot. In fact, in the Programmed Setup mode, the process can be done with a single button as part of a larger measurement procedure containing as many as 200 stored setups and measurement steps. It's all built into the scope — no external computer is required. Results can even be sent directly from 2430A memory to a printer. This can be done automatically as part of a 2430A programmed sequence or independently by using the 2430A Output button.

The Local Test™ platform

The built-in measurement capabilities illustrated by Figure 1 are part of a 2430A feature-set called Local Test™. The key Local Test features are Auto Setup, AutoStep, Waveform Parameter Extraction, and Save on Delta™. These features can be used individually or together to substantially increase

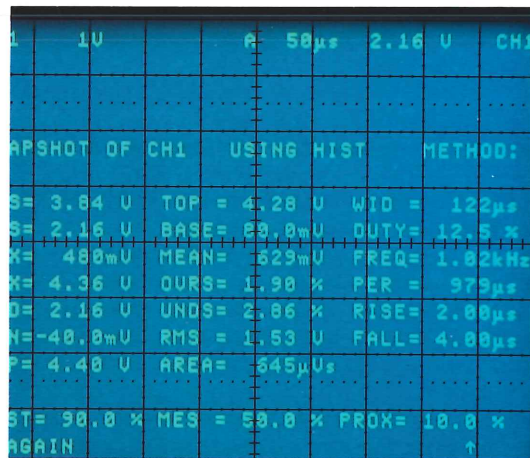


Figure 1. The Snapshot measurement feature automatically extracts 20 parameters from the digitized input waveform and displays the results as a measurement table.

test and measurement effectiveness and convenience. Additionally, their operation can be modified through on-screen menus to suit special needs. And complete setups can be stored in nonvolatile memory for later recall or for use in multiple-setup measurement sequences.

Auto Setup — single-button waveform viewing. The Auto Setup feature allows designers, researchers, evaluation engineers, or service personnel to quickly view different waveforms throughout a circuit or system by pressing a single button for scope setup. Simply attach the 2430A probe to any test point and press the Auto button. Within seconds, the unknown waveform appears on-screen as a stable, automatically triggered, scaled display.

For example, if you are working on a power supply design, you can quickly move through the circuit checking waveforms from line voltage to millivolt levels without continuous adjustment of the input sensitivity. Simply press Auto Setup, and amplitude scaling is done automatically for single or dual-channel displays.

Standard triggering and horizontal scaling are also taken care of automatically with Auto Setup. So, for example, you can probe a digital clock or strobe line first, then quickly look at the index or enable pulses on another test point — all just by pressing Auto Setup.

The Auto Setup function automatically senses the period of the input signal and determines the appropriate sweep speed. Common repetitive waveforms are shown with three to five cycles on screen. Or for pulse measurements, Auto Setup can be used in either the pulse or edge mode. In the pulse mode, the automatically set up display shows just the pulse or pulse width on screen so that low-duty-factor pulses can be examined in detail. In the edge mode, the acquisition display is automatically concentrated on either the rising or falling edge of the pulse.

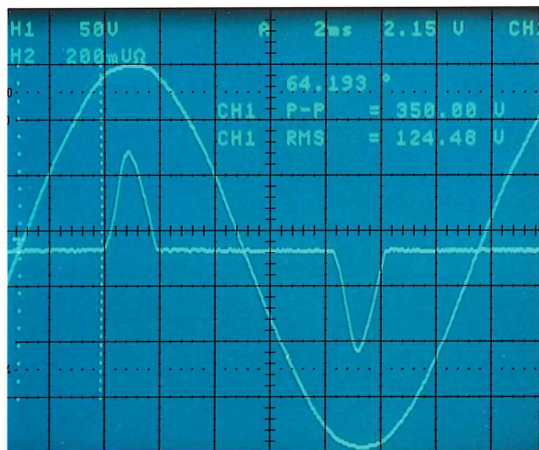


Figure 2. A dual-channel measurement using cursors for phase measurement and automatic Waveform Parameter Extraction for continuous updates of peak-to-peak and RMS level readings.

Waveform Parameter Extraction — automated measurements. With a waveform displayed on-screen, measurements can be made in several manners. Screen divisions can be counted the old-fashioned way and multiplied by scale factors to get waveform parameters such as risetime and pulse width. It's quicker and simpler, though, to manually position the 2430A waveform cursors on key waveform points and read the results directly from the screen readout. Or you can just push Measure and Snapshot and automatically get complete results like those in Figure 1. Or the 2430A can be set up for continuously updated readouts of up to four selected measurements along with the waveform display (see Figure 2).

In the case of Figure 2, the line voltage and charging current of a power supply are being acquired with the 2430A in dual-channel mode. Cursors have been manually brought up in the degrees mode and positioned for a phase measurement referenced to one cycle of the displayed waveforms. The phase difference between cursor positions is displayed in the readout near top-center of the screen. At the same time, just below the phase readout, automatic Waveform Parameter Extraction is continuously updating readouts of the RMS and peak-to-peak voltages for the channel 1 waveform.

Figure 3 shows an extension of this measurement using the Waveform Multiply mode to obtain a display of instantaneous "volts-squared" power. In this case, Waveform Parameter Extraction has been set up for a continuously updated display of waveform frequency and maximum amplitude.

Figure 4 shows still another example of Waveform Parameter Extraction being used in the continuous update mode. In this case, a pulse edge has been acquired using Auto Setup in the Edge mode with Waveform Parameter Extraction set for a continuously updated risetime measurement.

While Waveform Parameter Extraction simplifies individual measurements, its greatest value is in repetitive measurements. For example, with automatic parameter up-

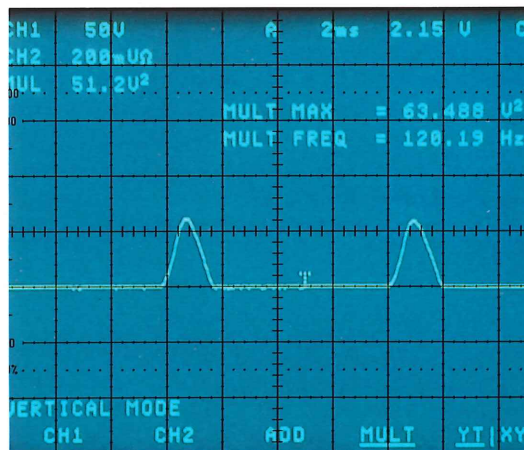


Figure 3. The waveforms in Figure 2 have been captured in Multiply mode to provide instantaneous "voltage-squared" power; Waveform Parameter Extraction provides continuously updated readouts of the power waveform's frequency and maximum value.

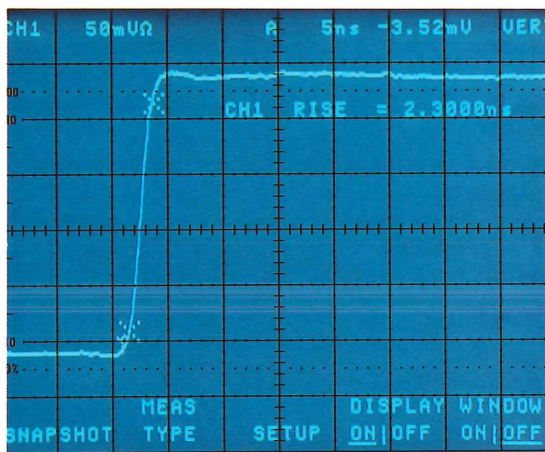


Figure 4. Using Auto Setup in Edge mode and Waveform Parameter Extraction, risetime checks can be quickly made at a series of test points, on a board run, or on a device lot.

dating, bus lines can be quickly probed to check pulse risetimes on each line or through the line drivers. The same can also be done for propagation delay (see Figure 5) by using the dual-channel mode and the propagation delay parameter extraction selection. Or, by selecting parameters, waveform levels can be quickly checked from point-to-point throughout a circuit or experimental setup. This is particularly useful on the production line or in calibration labs, where the continuously updated parameter readouts allow quick and direct observation of circuit adjustment effects.

Setup storage and AutoStep — even more automation. The measurement examples discussed thus far have all been treated as individual cases. This means doing individual front-panel setups each time a different measurement is needed. However, this needn't be the case with the 2430A.

The 2430A provides nonvolatile memory for storing as many as 200 front-panel setups. You can set up a risetime

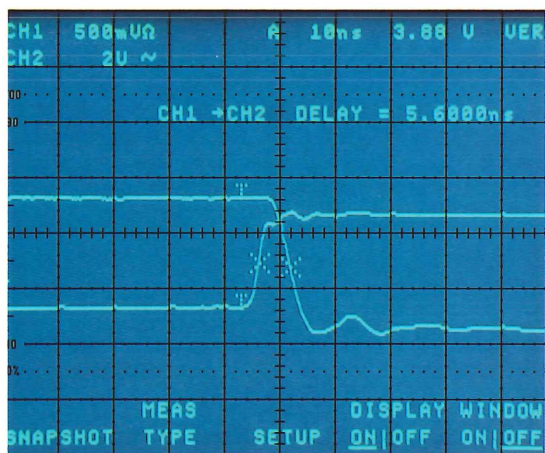


Figure 5. Propagation delay measurement made automatically with Waveform Parameter Extraction according to predefined threshold levels. (The "Xs" are automatic markers showing the location on the waveform of time-related measurements.)

measurement such as shown in Figure 4, store the settings in a labeled location, then set up the propagation delay measurement of Figure 5 and store its settings in another labeled location. Once stored, any labeled setup can be recalled as needed via a screen menu.

Or, by using the AutoStep feature, the stored front-panel setups and parameter extraction selections can be arranged in sequences for automatic execution. Dozens of measurement setups can be contained in an AutoStep sequence. An Actions menu (Figure 6) allows various control options to be included in the sequence. For example, the 2430A can be told to go through self calibration before a crucial measurement. Or the sequence can pause for operator interaction, such as attaching probes or adjusting the voltage levels or operating temperature of the device under test.

By using the AutoStep feature, complete measurement or evaluation sequences can be stored in the 2430A and executed automatically as needed. This improves measurement repeatability and efficiency when evaluating multiple boards in a production run for example, or when gathering experimental results over time or while the operating or environmental parameters vary.

Save on Delta — quick reference comparisons and babysitting for occasional faults. In some cases, specific waveform parameters are not as much a concern as whether or not a waveform fits within certain limits. For such cases, a limits envelope can be established using the 2430A envelope mode (see Figure 7). Then, using the Save on Delta mode, subsequent waveform acquisitions can be compared to the reference envelope for automatic pass/fail decisions. Any waveform that exceeds the bounds of the reference envelope is automatically saved in the 2430A waveform reference memory as a Save on Delta event.

In automated testing applications, Save on Delta allows fast waveform checks for overall shape compliance. In troubleshooting applications, Save on Delta can be setup to automatically monitor a line or test point for occasional faults. When a fault (e.g., level drift, noise spike, time jitter) causes

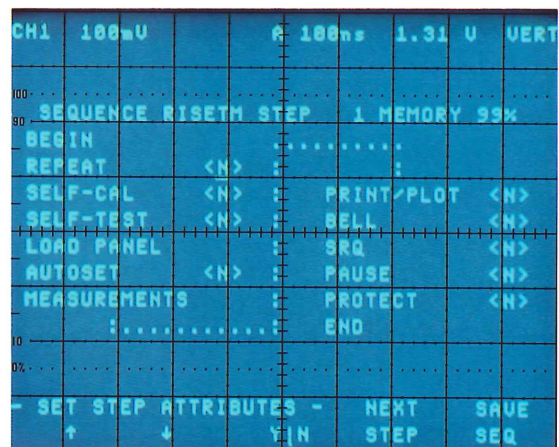


Figure 6. The AutoStep Actions menu used for setting up stored sequence execution and control.

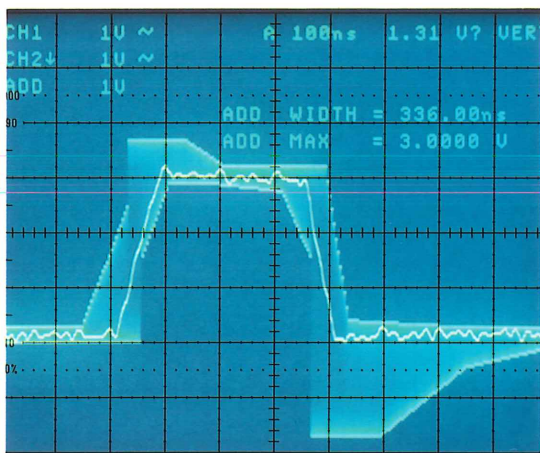


Figure 7. A telecommunications T-carrier waveshape specification envelope downloaded to the 2430A from a computer for use in Save on Delta testing. If the T-carrier pulse exceeds the bounds of the envelope mask, the faulting waveform is automatically captured by the 2430A as a Save on Delta event.

an envelope violation, Save on Delta automatically stores the violating waveform. No one has to sit and stare at the screen, waiting for a fleeting glimpse of a fault condition. Instead, the 2430A does the “babysitting” for you while you go about your other activities.

Putting Local Test to work

Figure 8 shows an example of putting the 2430A Local Test features to work in an automated test application. The test is run using the AutoStep function to automatically execute the stored front-panel setups and measurement selections. Testing includes making specific waveform parameter

measurements and then using the Save on Delta function for pass/fail evaluation of the overall waveshape. Testing also includes automatic output of waveform plots and measurements via a printer attached directly to the 2430A GPIB interface.

Entire test sequences such as this can be created and executed completely from the 2430A front panel — without using an external computer. Test sequences can also be transferred between 2430A scopes over a GPIB cable — still without using an external computer.

While a substantial degree of automation can be supported by the 2430A as a standalone portable oscilloscope, an external computer does offer some simplifications and further automation power. For example, AutoStep sequences can be transferred to and from test libraries archived on IBM PC diskettes. A computer can simplify generation of complex reference envelopes for Save on Delta applications. And a computer, such as an IBM PC, can offer waveform processing capabilities beyond the automatic parameter extraction built into the 2430A. To support such application requirements, a variety of IBM PC software packages are available from Tektronix or other manufacturers (see sidebar **Off-the-shelf software for your 2430A Digital Oscilloscope**).

And still more — all in a portable

While the above examples may seem extensive, they actually only briefly cover the built-in capabilities of the 2430A. For example, the 2430A provides waveform digitizing to a useful storage bandwidth of 40-MHz for single-shot events and to 150 MHz for repetitive waveforms. Additionally, glitch capture is provided on all sweep speeds to ensure viewing of noise spikes or circuit faults as narrow as two nanoseconds.

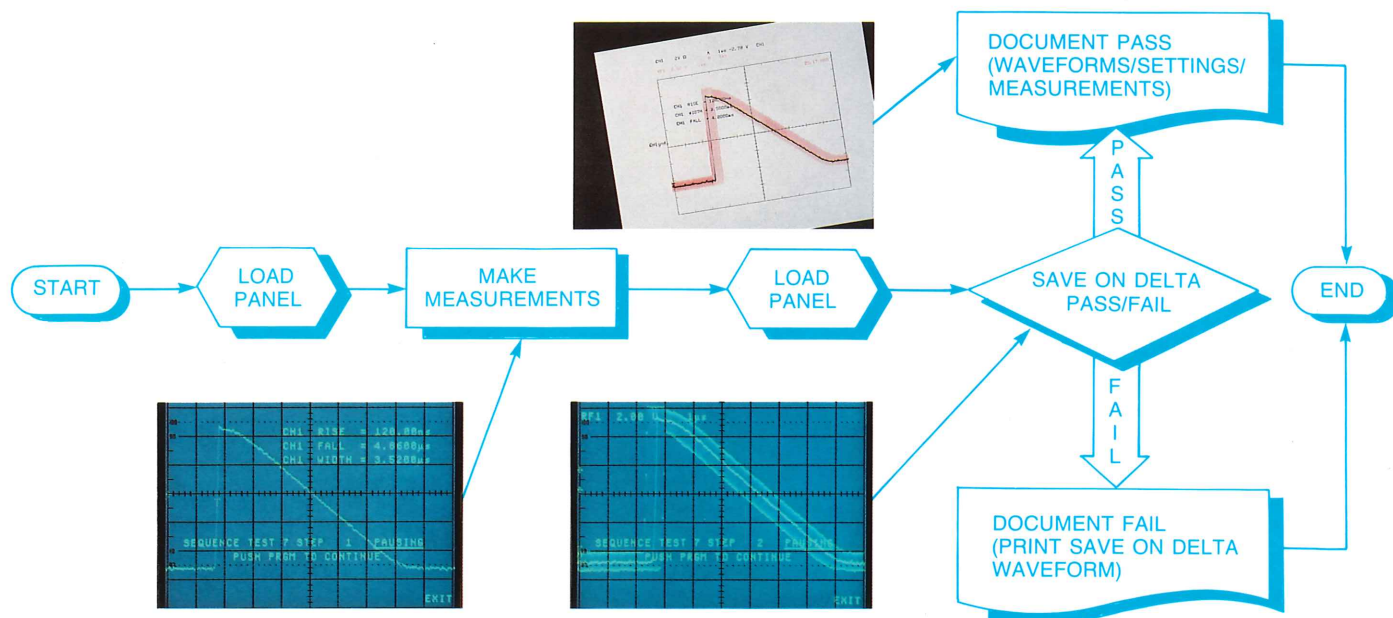


Figure 8. Flow diagram of a 2430A test sequence used for automatic parameter measurements and comparison of waveshape to a Save on Delta reference envelope.

Other waveform capture modes include enveloping for studying drift or other waveform trends and signal averaging to reduce random noise. Acquisition can also be augmented by delay-by-time or delay-by-events triggering to isolate waveform capture to a specific area or event within a string of events. And an optional Word Recognizer Probe can be added for 17-bit triggering on digital words.

In terms of built-in Waveform Parameter Extraction, only a few of the available measurements have been covered by the examples given here. A full list is provided in Table 1. Moreover, these measurements can be modified or constrained to meet further specialized needs. For example, a window function can be used to constrain parameter extraction to a selected area of the displayed waveform. Level references can also be defined. For example, pulse parameter extractions can be based on pulse top/base definitions by manual cursor placement, by measured pulse maximum and minimum values, or statistically by a histogram routine. Transition measurements (rise, fall, width, etc.) can also be redefined for any percent amplitude level (e.g., 0-100%, 10-90%, etc.) to accommodate measurement definitions used in different engineering and scientific disciplines.


And there are still other features — like an on-screen help function that describes any button, knob, or control on the 2430A. Just operate any control while in the HELP mode and

Table 1
Parameters Automatically Extracted
by the 2430A Digital Oscilloscope

Risetime	Minimum Amplitude	Top
Falltime	Maximum Amplitude	Base
Area	Frequency	Distal
MS Volts	Duty Cycle	Mesial
Propagation Delay	Pulse Width	Proximal
Period	Peak to Peak	Overshoot
Vertical Midpoint	Mean	Undershoot

a complete description of the control appears on the 2430A screen.

Want to know more?

To find out more about the 2430A Digital Oscilloscope and its built-in measurement and automation features, check the 2430A box on the **HANDSHAKE** reply card. Complete details will be mailed directly to you. Or if you'd like an on-site demonstration of the 2430A, check the box requesting a call by a Tektronix Sales Engineer or contact your local Tektronix Field Office or representative. 

Off-the-shelf software for the 2430A Digital Oscilloscope

ASYST Scientific Software

ASYST turns your IBM PC, PC/XT, PC/AT, or compatible into a powerful scientific workstation. It consists of up to four modules covering system, graphics, and statistics routines; data acquisition routines; data analysis routines; and PC-to-GPIB instrument interfacing.

Tektronix Signal Processing and Display (SPD) programs

SPD is a comprehensive package from Tektronix which provides access to 196 processing, analysis, and data-to-display functions. Operations include FFT, convolution, correlation, etc. This package runs on the IBM PC, PC/XT, PC/AT, or compatibles. Access to waveform processing and graphics is provided through on-screen menus. Software interfaces are also

provided for accessing the function library through compiled basic or C language environments.

Tektronix GURU II


GURU II contains simple but powerful GPIB control software plus a PC-to-GPIB interface card and a GPIB cable for interfacing your 2430A to an IBM PC, PC/XT, PC/AT, or compatible. GURU II's menu-driven Test Procedure Generator (TPG.BAS) allows you to generate BASIC language test programs — without writing a single line of code. This is an ideal package for people who want quick results without the need to learn the details of programming.

Tektronix Measurement Application Programs (TekMAP)

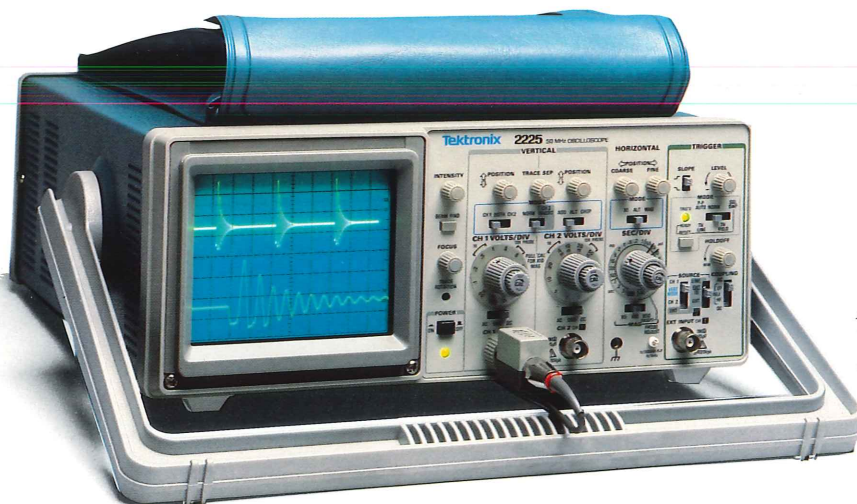
TekMAP programs extend the ver-

satility of Tektronix digitizing products by integrating them with Tek controllers, IBM PCs, and HP 200 Series technical computers. The programs are all menu driven, including the TekMAPS time and amplitude measurement software, which provides pulse parameter analysis, fast Fourier transforms (FFT), and propagation delay measurements.

Lotus Measure

Lotus Measure runs on IBM PCs and compatibles. It transfers data directly from instruments into Lotus 1-2-3 spreadsheets for immediate display, analysis, and storage. It works as part of 1-2-3, sharing the same user interface and macro environment. Measure can be used in a broad range of applications and supports the GPIB and RS-232C buses and selected data acquisition boards. 

Tek goes under \$1000 with new portable scope



The new 2225 50 MHz Oscilloscope is priced at \$995 (U.S. dollars), yet provides professional features and quality backed by a three-year warranty.

The new 2225 50 MHz Oscilloscope from Tektronix is designed for economy plus performance — in the laboratory, on the bench, in production, in the classroom, or for field service. For economy, look at the low price — \$995 (U.S. dollars). For performance, the 2225 is loaded with features — some found only on more expensive oscilloscopes. 2225 features include:

- 500 microvolts/division sensitivity
- High- and low-frequency trigger reject
- Peak-to-peak auto, normal, and single-sweep triggering
- TV field and line triggering
- X5, X10, and X50 Alternate Horizontal Magnification

And all this is backed by a three-year warranty, the first in the low-cost scope market.

With its 50-MHz dual-channel inputs and extensive triggering features, the 2225 makes an ideal lab or service bench tool. It has the capabilities to cover many complex measurement and alignment procedures. Yet it's easy to operate, making it an ideal tool for first-time scope users. And its lightweight ruggedness makes it a ready and able companion for field service trips.

Loaded with features

For measurement capability, the 2225 offers two input channels. These can be used singly or in dual-channel mode with signals to 50 MHz.

Or, with the flick of a switch, the two channels can be displayed in X-Y mode. In the lab or on the production floor, the X-Y mode is particularly useful for monitoring sensor outputs. In the classroom, the single-switch X-Y mode allows students to explore Lissajous patterns without getting bogged down in complicated scope setups.

High sensitivity is another key feature, particularly for sensor monitoring, read/write head servicing, or any other low-level signal applications. With 500 microvolts/division

sensitivity available on both channels, the 2225 is orders of magnitude ahead of other low-cost scopes.

Of course, noise can cause triggering problems on high-sensitivity settings. But the 2225 takes care of this by offering a high-frequency trigger reject feature. A low-frequency reject setting is also provided for line EMI and supply ripple problems that can make triggering difficult on any signal level.

Other triggering features include AC and DC coupling, single sweep, and TV field/line triggering (see Figure 1). With the increased use of video monitors and closed-circuit TV in production, security, and general office systems, TV field and line triggering is becoming an indispensable service feature.

For getting a closer look at signal details, there's the Alternate Horizontal Magnification feature. For applications such as risetime and delay measurements, this provides the power of a delaying time base scope without the operational complexity. Simply move the slide switch to the X5, X10, or X50

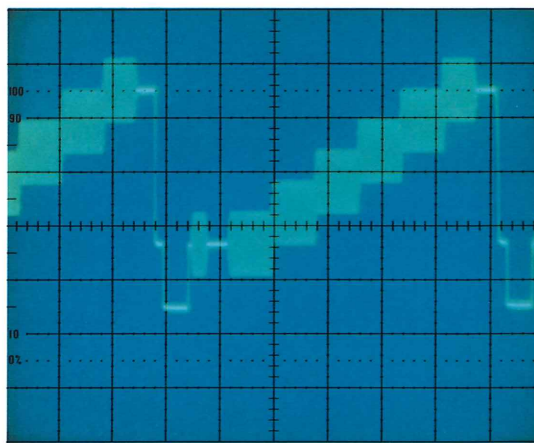


Figure 1. Video line signal displayed using the TV Field/Line triggering feature.

Under \$1000 portable ...

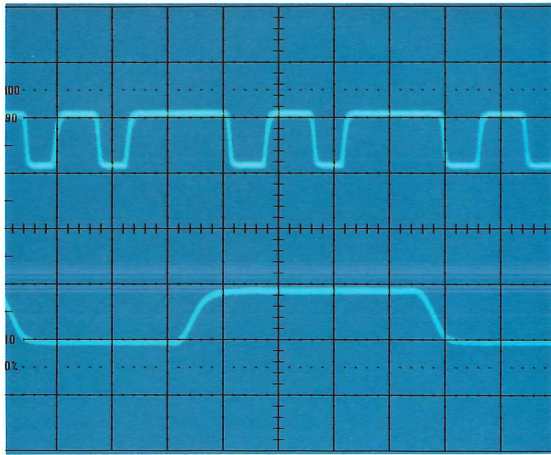


Figure 2. *Alternate Horizontal Magnification provides delaying time base capabilities with simple slide switch selection for X5, X10, or X50 expansion.*

setting and you get horizontal trace expansion for detailed timing measurements (see Figure 2).

Tough and light

Not only is the 2225 a highly capable measurement tool, it's also ready to go where the measurements are. At under 15 pounds, it's a lightweight among portable scopes. But, when it comes to taking field service punishment, it's heavyweight tough.

The 2225 is shock tested to 30 g, and vibration tested to 2.4 g, 55 Hz. It also meets MIL-T-28800C specifications for operation in up to 95% relative humidity. Plus its specified operating temperature range is 0 to +40 degrees C.

Take the 2225 out of a car trunk on a crisp winter morning or a muggy summer afternoon, and it's ready to go to work while other low-cost scopes are still trying to recover from environmental shock. And the 2225 goes to work quietly too, without interfering with other equipment. That's because it also meets VDE 0871 Class B and FCC, Part 15, Subpart J, radiated and conducted emissions requirements.

Three-year warranty and probes too

But wait! All of this measurement capability and environmental ruggedness in a scope for under \$1000? Surely that can only be done by skimping on the extras. That's how other low-cost scopes get to be low cost. But not the 2225.

Take probes for example. They're often \$50 to \$100 options — each. However, with the Tektronix 2225, you get two 10X probes as standard accessories. They're included in the base price along with the manual, power cord, and power cord clamp.

There's no skimping on the warranty either. The Tektronix 2225 50 MHz Oscilloscope comes with a three-year warranty. All parts and labor are covered, including the CRT.


No skimping on support

There's no lack of support for the 2225 either, even at this low price. Backing up the three-year warranty are Tektronix Service Centers located around the world and our commitment to the long-term service of your instruments.

In addition, there's training. For example, **The XYZ's of Using a Scope** is a complete primer that covers the essentials of oscilloscope operation and applications. For the experienced scope user, it serves both as a review and a reference. The beginning scope user will find it to be a useful instruction and learning aid. A series of technical briefs provides further details on scope setup and specific measurements. This literature is available at no charge.

See it in action in a free video

A free demonstration video tape is available to show the 2225 in action. It summarizes the features and basic performance of the 2225 to show how it will work in your application.

For a copy of the available literature or the free video tape demonstration on the 2225, simply use the reply card in this issue of **HANDSHAKE**. U.S. customers can call the Tektronix National Marketing Center literature desk toll free — 800-433-2323 (in Oregon call 503-627-9000 collect). And tell them you saw it in **HANDSHAKE**. 


Call and charge it

With all of its capabilities, warranty, and its low price, the Tektronix 2225 50 MHz Oscilloscope is one of the easiest scopes to cost justify. And we make it easy to buy too.

The 2225 can be ordered by phone from the Tektronix National Marketing Center by calling our toll-free ordering number, 800-426-2200 (in Oregon call 503-627-9000 collect), Monday through Friday, 6 a.m. to 5

p.m. Pacific time (U.S. orders only). And for your convenience, payment can be made by Visa or MasterCard. All Tektronix volume purchase discounts apply to National Marketing Center orders. In addition, ordering a 2225 through the National Marketing Center gives you a 30-day return option. If the instrument doesn't match your needs as expected, return it within 30 days of purchase for a full

refund.

The Tektronix 2225 50 MHz Oscilloscope can also be ordered from any Tektronix Field Office, or it can be purchased directly from any Tektronix authorized distributor. To obtain the location and telephone number of your nearest Tektronix Field Office or authorized distributor call 800-426-2200. 

Network and impedance analysis with the 2430

Alan Selfridge, Ph.D.
Ultrasonic Devices, Inc.
Milpitas, CA 95035



With the software described in this article, the 2430 can be used for network and impedance analysis.

Teaming the 2430 with the IBM PC/AT

Specialty Engineering Associates needed to analyze the complex network parameters of an acoustic hydrophone preamplifier. To do this task, the system shown in Figure 1 was set up.

In this system, a 2430 and an IBM PC/AT exchange data and commands through an IEEE 488, or General Purpose Interface Bus (GPIB). The device under test (DUT) — the preamplifier in this case — is driven by a signal generator. Its input and output signals are acquired and digitized by the 2430. The PC/AT controls the 2430 and calculates measurement values. The plotter

records those values.

Figure 2 shows a flow chart of the software used to control the system.

The system as configured does not require a synthesizer or even a programmable function generator. While this limits the equipment required, a programmable function generator would simplify things — the code could be simplified and the measurement period reduced significantly if the program always knew in advance what the waveform frequency would be. Furthermore, having a more stable frequency source would make measuring high-Q resonators much easier.

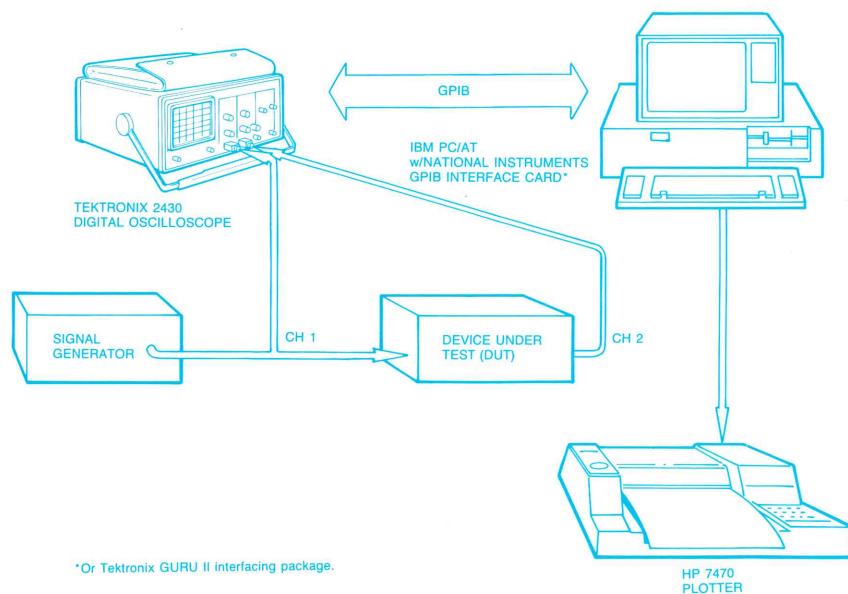


Figure 1. The 2430-based network analyzer as configured by Specialty Engineering Associates.

Measuring gain and phase vs frequency

To measure and plot gain and phase versus frequency, the operator selects a starting frequency for the plot and runs the program called **RATIO**. This program initializes the plotter and oscilloscope, then reads the waveforms from Channel 1 and Channel 2. Since Channel 1 is typically the cleaner signal, it is used to determine the frequency of the generator.

The computer then calculates the relative phase and amplitude from the input and output waveforms, placing a point on the graph paper corresponding to the relative phase at the measurement frequency. Gain information is stored

for subsequent plotting (or displayed along with phase if screen graphics are used). The operator manually sweeps the signal generator through the desired frequency range and phase versus frequency is plotted.

When a key is hit, the program stops data collection, draws the axes, queries the operator for scale information, and plots the gain curve. Figure 3 shows a typical plot obtained from analyzing the preamplifier.

If the system computer contains an 80286 processor, two to four points can be plotted per second. If phase information is not required, or if only a scalar amplitude versus frequency plot of a single signal is desired, the measurement rate increases to about five points per second. The plot in Figure 3 was done in about two minutes.

Plotting complex impedance

A simple reconfiguration enables the system to plot the ratio of input voltage and input current — complex impedance. To determine the complex impedance of a 1 milliHenry (mH) inductor, for example, a Tektronix CT2 Current Probe is substituted for the voltage probe attached to the Channel 2 input of the 2430. The current probe is placed at the input of the DUT as shown in Figure 4.

This configuration was used to produce the curve shown in Figure 5. Here we see that the 1 mH inductor being measured resonates at about 1 MHz, above this it begins to act like a capacitor. This is valuable information for many

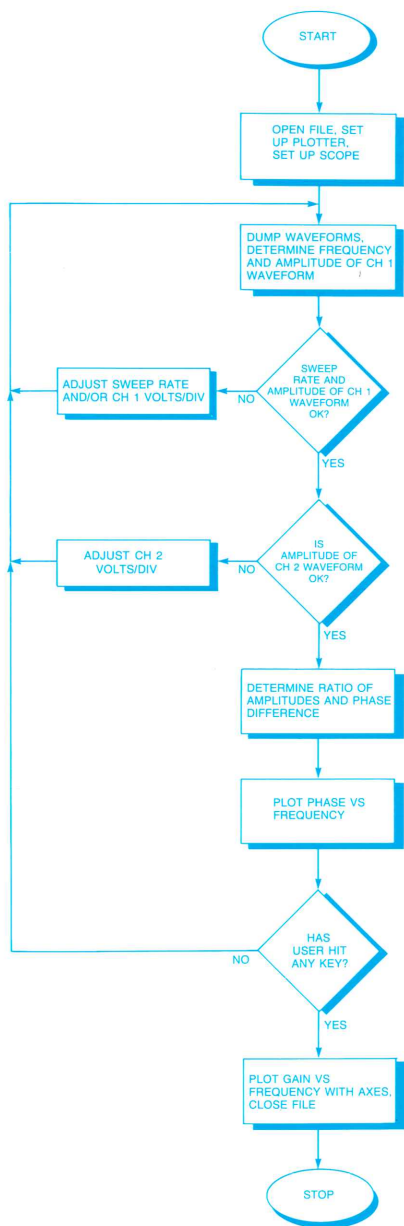


Figure 2. Flowchart of software used to measure and plot gain and phase versus frequency.

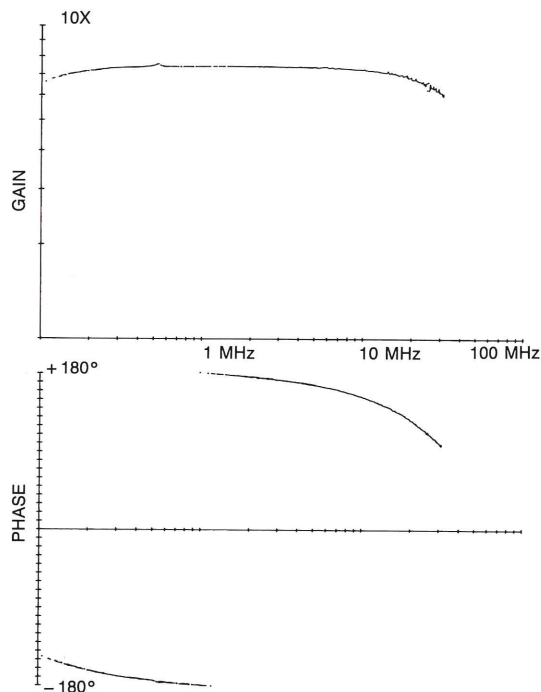


Figure 3. Plot of the gain versus frequency characteristics of an acoustic hydrophone preamplifier using the 2430-based network analyzer.

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04

(check 1 only)

- ☐ EH Basic R&D
☐ FD Calibration
☐ BQ Computer-aided design
☐ AN Consulting
☐ BB Design

☐ BG Component design

☐ BC Hardware design

☐ BJ Software design

☐ BT System design

☐ JA Education/training

☐ AM Health/medical

☐ AA Management

☐ AA Company management

☐ BA Engineering management

☐ DA Manufacturing management

☐ DC Manufacturing production

☐ DE Manufacturing test

☐ GA Marketing/sales

☐ FE Metrology

☐ GE Programming

☐ AD Purchasing

☐ DH Quality control/standards

☐ DK Semiconductor test

☐ FB Service/maintenance

☐ GD System installation

☐ BL Test engineering

☐ ZZ Other _____

Your purchasing involvement

01

☐ 05 Write specifications

☐ 04 Recommend equipment

☐ 06 Sign purchase orders

☐ 01 No purchasing involvement

Best description of your company

06

(check 1 only)

Manufacturing

☐ AB Aerospace/aircraft

☐ AC Automotive

☐ BH Automatic test equipment

☐ BJ Biomedical equipment

☐ AD Chemical/plastics

☐ BA Communications equipment

☐ CB Consumer equipment

☐ AE Computers

☐ AF Computer peripherals

☐ DG Food products

☐ BE Electrical equipment

☐ BF Electronic components

☐ BG Electronic test equipment

☐ CH Industrial automation

☐ CF Industrial electronics

☐ DA Military equipment

☐ CG Semiconductor manufacturing

☐ ZZ Other _____

Non-manufacturing

☐ MB Consulting

☐ KA Communications

☐ MC Education

☐ MG Graduate programs

☐ ME 2 or 4 year college

☐ MF Vocational school

☐ MH In-house training

☐ QB Government (non-military)

☐ RB Health/medical

☐ RA Leasing/rental

☐ QD Military/defense

☐ RD Nuclear industries

☐ RE Petroleum/energy

☐ RH Service/maintenance

☐ NE System integration

☐ KC Telephone

☐ KD TV/CATV/radio

☐ ZX Other _____

Measurements you make

Signal frequency (check all that apply) 20

☐ 11 DC levels

☐ 01 Ultra-low (DC to 100 KHz)

☐ 06 Low (100 KHz to 10 MHz)

☐ 07 Mid (1 MHz to 300 MHz)

☐ 08 High (100 MHz to 2 GHz)

☐ 09 Very-high (1 GHz to 10 GHz)

☐ 10 Ultra-high (above 10 GHz)

Types of signals (check all that apply) 39

☐ 01 Analog signals

☐ 02 Digital signals

☐ 03 Fiber optic signals

☐ 04 Microwave signals

☐ 05 RF signals

☐ 06 Television signals

☐ 07 Other _____

Instruments used/product interest 02

(check all that apply)

☐ AB Accessories

☐ AD Current probes

☐ AE Voltage probes

☐ ED Audio analyzers

☐ HH Arbitrary waveform generators

☐ EC Counter/timers

☐ BE CRT cameras

☐ EB Digital multimeters

☐ HF Digitizers

☐ BK Digitizing cameras

☐ EJ Instrument controllers

☐ QM Logic analyzers

☐ PA Portable oscilloscopes

☐ HA Plug-in oscilloscopes

☐ HB CRT storage oscilloscopes

☐ HK Digital storage oscilloscopes

☐ KC Modular test instruments

☐ EA Power supplies

☐ EN Pulse generators

☐ JA Semiconductor curve tracers

☐ EP Signal switching/interconnection

☐ FB Spectrum analyzers

☐ KB Word generators

☐ ZX Other _____

Instrumentation bus used

40

(check all that apply)

☐ 01 GPIB (IEEE 488)

☐ 02 RS-232C

☐ 03 VME

☐ 04 MAP

☐ 05 ETHERNET

☐ 06 Other _____

Instrument controllers used

41

(check all that apply)

☐ 01 Tek 4041

☐ 02 Tek 4050-Series

☐ 03 IBM PC/PCXT or compatible

☐ 04 IBM AT or compatible

☐ 05 Hewlett Packard — Model # _____

☐ 06 DEC PDP-11

☐ 07 DEC VAX/MicroVAX

☐ 08 Fluke — Model # _____

☐ 10 Apple II

☐ 11 Apple Macintosh

☐ 12 Other _____

Application of above controllers

42

(check all that apply)

☐ 01 Automatic test

☐ 02 Data acquisition

☐ 2A D/A conversion

☐ 2B Oscilloscope waveforms

☐ 2C General measurements

☐ 03 Data base

☐ 04 Desktop publishing

☐ 05 Device characterization

☐ 06 Graphic display

☐ 07 Instrument control

☐ 08 Manufacturing test

☐ 09 Presentation graphics

☐ 10 Software development

☐ 11 Spread sheets

☐ 12 Statistics

☐ 13 Waveform analysis

☐ 14 Word processing

☐ 15 Other _____

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- ☐ 5-1 Under 1 year
☐ 5-2 1-2 years
☐ 5-3 2-5 years
☐ 5-4 Over 5 years

How did you hear about HANDSHAKE?

- ☐ 6-1 Tektronix Sales Engineer
☐ 6-2 Trade show
☐ 6-3 Fellow worker
☐ 6-4 Received with new instrument
☐ 6-5 Received unsolicited via mail
☐ 6-6 Other _____

When you receive HANDSHAKE do you?

- ☐ 7-1 Read immediately
☐ 7-2 Read selected articles
☐ 7-3 Read later
☐ 7-4 Seldom or never read

Which of the following would you like to see more of in HANDSHAKE?

- ☐ 12 New product descriptions
☐ 13 Application articles
☐ 14 Measurement tutorials
☐ 15 Design concept tutorials
☐ 16 Answers to measurement/instrumentation questions
☐ 17 Other _____

If HANDSHAKE were no longer available, where would you get the same information?

- ☐ 18 Call Sales Engineer
☐ 19 Product literature
☐ 20 Advertisements
☐ 21 Magazine articles
☐ 22 Could not get information

Which of the following trade journals do you read on a regular basis?

- ☐ 33 EDN
☐ 34 Electronics
☐ 35 Electronic Design
☐ 36 Electronic Test
☐ 37 Personal Engineering & Instr news
☐ 38 Test and Measurement World
☐ 39 Other _____

What company-sponsored journals similar to HANDSHAKE do you read on a regular basis?

After reading do you?

- ☐ 8-1 File for future reference
☐ 8-2 Pass on to others. How many? _____
☐ 8-3 Discard 9

Please rate HANDSHAKE articles

- ☐ 10-1 Of little application
☐ 10-2 Somewhat applicable
☐ 10-3 Of general interest
☐ 10-4 Relevant to job
☐ 10-5 Very relevant to job

How do you view HANDSHAKE as a source of technical information?

- ☐ 11-1 An important reference
☐ 11-2 A frequent reference
☐ 11-3 An occasional reference
☐ 11-4 Of little or no technical value

What past action have you taken as a result of reading HANDSHAKE?

(check all that apply)

- ☐ 23 Asked for more information
☐ 24 Contacted Sales Engineer for demo
☐ 25 Changed measurement methods
☐ 26 Purchased equipment/system
☐ 27 Other _____

What Tektronix publications do you use as a source of product information?

(check all that apply)

- ☐ 28 Tektronix products catalog
☐ 29 Product brochures/data sheets
☐ 30 Product instruction manuals
☐ 31 HANDSHAKE
☐ 32 Other _____

Do you have an article idea you would like to write for HANDSHAKE?

- ☐ 40-1 Yes ☐ 40-2 No

What topics would you like to see covered in HANDSHAKE?

Comments: _____



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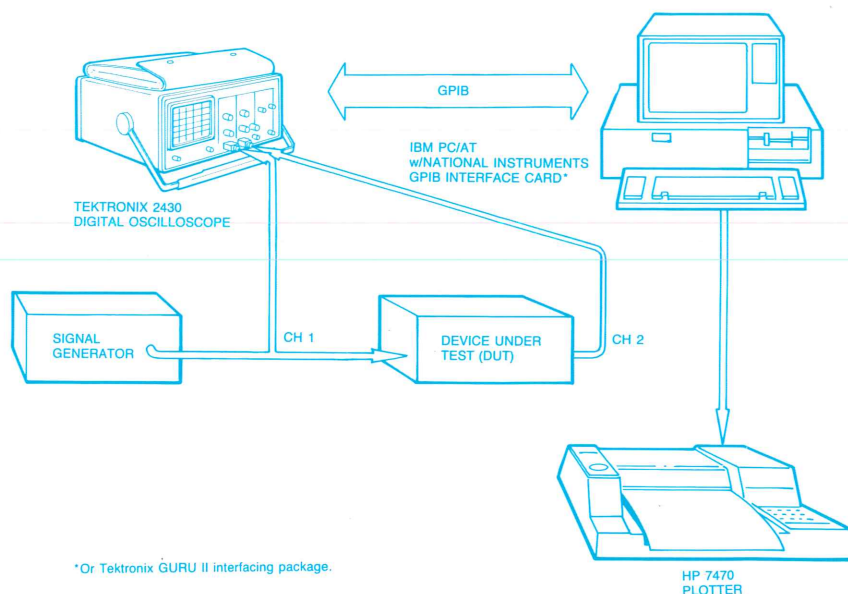


Figure 4. The 2430-based system reconfigured for measuring complex impedances (voltage/current versus frequency).

design applications such as the design of low-pass filters. The complexity of the impedance of many real devices, especially resonant devices, easily justifies this simple, easy-to-use testing method.

Obviously the above techniques have limitations. In particular, the Nyquist criterion warns us to never exceed half the sampling frequency of the scope — the 2430 samples at 100 MHz. This rate constrains the system to measurements below 50 MHz; 30 MHz is a conservative upper limit. The region between 30 and 50 MHz should be handled cautiously.

The range of impedances that can be measured by this system is dependent upon the sensitivity of the current probe and its insertion resistance. The CT2 and 2430 combination enable us to detect the effects of a few picofarads.

The lowest impedance measurable is about 0.1 ohms — the insertion impedance of the current probe. Range could be extended somewhat with various de-embedding techniques or additional hardware, but in our work we found these techniques unnecessary.

Measuring frequency — two methods

A significant portion of program code is used to determine the frequency of the 2430-acquired waveforms. Two methods can be used — either a time-domain analysis or a frequency-domain FFT (fast Fourier transform). The time-domain approach, can be very useful when dealing with short, gated tone bursts (common in reverberant, acoustic systems). In such bursts, one has only a few cycles to work with, and the frequency must be determined by interpolating zero crossings.

Several problems can crop up when using the zero-crossing approach. One interesting phenomenon is that amplitude measured at a quarter of the sampling frequency can be quite unstable when only a few cycles are averaged. This instability is probably due to the way the system interpolates non-repetitive processes. When frequencies differ between bursts, repetitive or averaging modes cannot be used.

A more serious problem occurs when the DUT itself adds higher-order harmonics to the waveforms impressed across it. (This happens in some passive “linear” devices. The problem intensifies near a low-impedance point if the device has one.) These little “wa-hoos”, or sub-waves, form on the basic sinusoid and can be extremely confusing to the computer if they happen near a zero crossing.

FFT techniques can get around these nuisances if sufficient cycles are available. FFT techniques also make it easy to

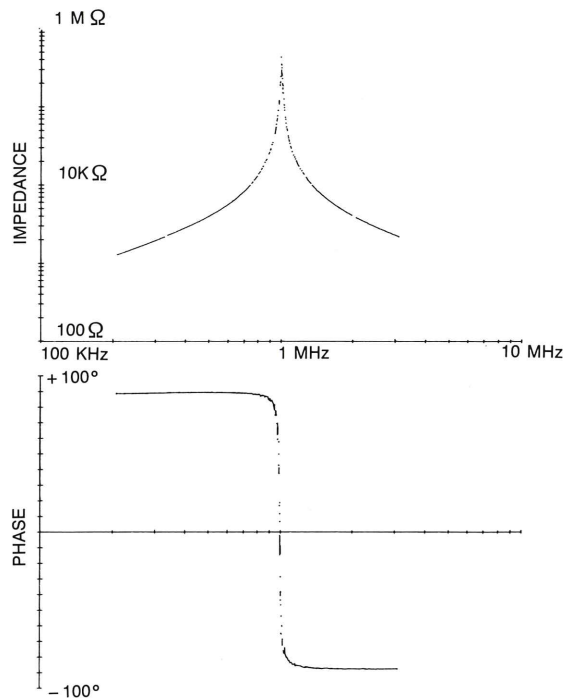


Figure 5. Plotting the complex impedance (top) and phase (bottom) reveals that the device under test (a 1 mH inductor) resonated at near 1 MHz.

compare the phase of two separate signals. (This is not as easy to do quickly in the time domain.) For FFTs to work in this application, however, we found it necessary to find one that is extremely fast. Most FFT routines available for the IBM PC/AT use floating-point numbers and take roughly 1.6 seconds to transfer a 1024-point waveform using a computer containing an 80287. Fortunately, with the INTEGER FFT¹ program, a 1024-point INTEGER FFT can be done in roughly 0.12 seconds working with an IBM PC/AT and an 8-MHz clock — without the 80287. Use of INTEGER FFT techniques makes the program robust and reliable.

The programs discussed above are mostly written in Microsoft Fortran, Version 4.0, though a few subroutines are in assembly language. The Hercules and EGA graphics packages are running flawlessly. Use of a hardcopy plotter such as the HP 7470, however, makes it impossible to draw two curves simultaneously. Plotting therefore is a two-step process.

Opportunities for digital power in other fields

No doubt there are many other novel and useful applications for the power of the Tektronix 2430 in similar applications, for example, plotting capacitance versus voltage at

various frequencies. This type of measurement should greatly interest semiconductor designers. In addition, there are probably many applications in vibration analysis and biomedical engineering, to name only a few, where the power of these new digital tools can be applied.

For more information

For more information about these programs or other possible applications, please contact the author at:

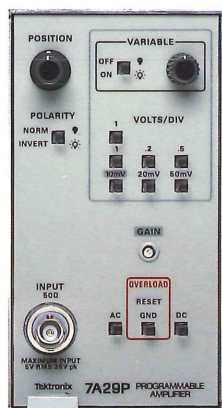
Ultrasonic Devices, Inc.
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Milpitas, CA 95035
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For information on the 2430, see the article **The 2430A — full measurement automation in a portable digital oscilloscope** in this issue. The 2430A Digital Oscilloscope is an updated version of the 2430 — all programs developed for this application will run on both the 2430 and the 2430A. Use the reply card in this issue of **HANDSHAKE** for literature describing the 2430A. For a demonstration, call your local Tektronix Field Office or representative.

¹ INTEGER copyright 1985 by John Hartwell, Rt. 4, Box 1540, Hillsborough, NC 27278.



The 7A29P — programmable high-bandwidth amplifier for the 7912HB and the 7912AD



The Tektronix 7A29P Programmable Vertical Amplifier provides up to 750 MHz performance for Tektronix 7000-series programmable digitizers. The perfect companion for the 7912HB Programmable Transient Digitizer (see **7912HB — Real-time digitizing to 750 MHz** in the Spring 1987 **HANDSHAKE**), the 7A29P provides maximum bandwidth with full vertical programmability. The 7A29P is equally at home in the 7912AD Programmable Transient

Digitizer. Table 1 shows the basic performance of the 7A29P when used with either the 7912AD or the 7912HB.

Beyond high bandwidth with full vertical programmability, the 7A29P provides programmable vertical deflection factors from 10 millivolts/division to 1 volt/division (80

Table 1
7A29P Bandwidth and Risetime Performance
in the 7912AD and 7912HB

Transient Digitizer	Bandwidth (-3 dB)	Risetime
7912AD	500 MHz	750 picoseconds
7912HB	750 MHz	575 picoseconds

millivolts to 8 volts full scale). Input impedance is 50 ohms. An automatic-disconnect circuit opens to protect the input circuitry if the applied signal exceeds 5 volts RMS (25 volts peak) or 0.5 watt-seconds.

If you're already using a 7912AD or 7912HB, the 7A29P will complete your programmable transient digitizer system. Check the appropriate box on the **HANDSHAKE** reply card for a data sheet on the 7A29P or contact your local Tektronix Field Office or sales representative for information.



Putting GPIB systems to work on everyday test needs

Marshall E. Pryor

2400-Series Product Marketing Manager

Portable Instruments Division

Tektronix, Inc.



GPIB instruments such as the Tektronix 2400-Series analog Oscilloscopes simplify everyday measurements.

Engineering bench measurements, metrology, calibration, incoming QC, manufacturing test, and field service are just a few of the areas that stand to benefit from new automation capabilities appearing on the measurement scene. These capabilities have evolved across several industry fronts, rather than as any single concerted effort. The end result, however, is that instrumentation, software, and controllers are finally offering the right feature mix for simple and economical measurement automation in far more areas than ever before.

In some cases, the features now being built into many instruments are sufficient in themselves to automate a lot of day-to-day measurement activities. In other cases, particularly where higher levels of automation are desired, these built-in control and measurement features can be used to advantage with a small computer equipped for GPIB programmability — an IBM PC or compatible for example. This offers compact economy for the engineering bench as well as portable automation for field service or production floor activities.

The new feature mix

Many instrument manufacturers are now including full GPIB programmability (general purpose interface bus conforming to IEEE Standard 488) in their instruments as a matter of course. At the same time, they are including more built-in measurement and processing features to simplify both stand-alone and system use of their instruments.

The 2400-Series analog scopes from Tektronix are a case in point. These scopes feature measurement cursors and options for fully integrated DMM and counter/timer capabilities along with word recognizer and TV triggering options. Moreover, initial setup for waveform viewing or measurements is simplified to a single-button Auto Setup function. The built-in front-panel programming required for this has been extended to cover all controls — including the integrated measurement options (DMM, counter/timer, etc.). Along with this programmability, built-in memory allows up to 30 complete front-panel setups to be stored in the scope and recalled by front-panel buttons. Setups can even be arranged in measurement sequences for execution by a STEP button.

This type of built-in measurement and control automation in a scope — or any other kind of instrumentation — simplifies and expedites day-to-day measurements. It also relieves system software burdens since many complex instrument functions can be executed by the scope alone or by single bus commands when a controller is used. For example, a built-in Auto Setup feature on many instruments establishes a stable, properly scaled, on-screen display of most signals with a single command. This eliminates the extensive programming previously required over the GPIB.

At the same time, instrument manufacturers are supporting instruments with a variety of control software. These packages range from general-purpose analysis routines, such

Putting GPIB systems to work ...

as pulse parameters, to automatic test program generators that allow menu-driven system configuration for virtually any application.

In many cases, this new GPIB control software is available for use on small computers such as the IBM PC or compatibles. This offers unprecedented economy for small-scale automation since many facilities already have a PC available. The GPIB interface and control software can be added for under \$1000. Where more extensive control — especially interrupt processing for multiple instruments — becomes necessary, more specialized controllers and software are available. These too have been augmented, in many cases, by automatic test program generation packages.

The end result is that measurement automation can begin with standalone instruments providing direct measurement capability, Auto Setup, or setup sequencing and progress smoothly to nearly any level of automation desired. As always, however, measurement automation at any level requires careful system definition and implementation.

Defining the system

The system definition process begins with exploring some basic questions:

What is your test strategy? At what point in the manufacturing or development process will testing be done? What test processes will be used? What parameters need to be tested and to what tolerances? What type of test fixtures are to be used? These and many other testing strategy questions need to be worked out before proceeding with system definition and design. For best results, this stage should involve an open discussion between all those who have a stake in the outcome — engineering design, product manufacturing, test system design, as well as others.

What kind of tests will the system perform? Is production testing the goal? If so, full automation and high system throughput are probably primary concerns. On the other hand, a system used to characterize components, analyze failures, or automate various troubleshooting or service activities will benefit more from added accuracy, higher flexibility, and an interactive operator interface.

What are the data acquisition requirements? Will the system make simple measurements? Will it analyze waveforms? How many channels are required? Many applications require several types of measurements (timing, voltage, etc.). Can these be served by the facilities of a single instrument?

For example, the Tektronix 2445A, 2465A, and 2467 Oscilloscopes provide a variety of waveform analysis capabilities through on-screen measurement cursors. However, this measurement capability can be multiplied several times over with options for a fully integrated DMM, Counter/Timer/Trigger with Word Recognizer, and Television Waveform Measurement System. By combining the scope, a DMM, and counter/timer facilities into a single instrument, you get economies of price, system development, and

system operation over using three or four separate instruments to perform the same measurement job.

Will processing of raw data be required? If special processing is required, either the instruments or the controller must perform the processing within the required time. Processing by the controller requires additional software investment. Built-in instrument processing, by contrast, is often more direct and more economical.

Will the system be fixed in one location or is portability required? A fixed, rack-mounted system is fine for many production applications, but field testing or engineering applications often require a compact, portable system.

How will the operator interact with the system? One of the primary goals of automation is to reduce operator burden. Doing this requires careful attention to the human interface. Simple prompting instructions and minimal dependence on operator controls is important. Yet, people still hold the lead in pattern recognition and intelligent decision making. For example, a trained operator can quickly place cursors for a risetime measurement on a highly distorted or non-standard pulse shape. Doing the same job without human assistance can require extensive software development and lengthy algorithms that extend run time. Depending upon the application, a blend of machine and operator capabilities often produces the most efficient, reliable test system.

Choosing system components

After considering the basic system definition questions, the process of component selection can begin. This will be based on fundamental measurement requirements (e.g., bandwidth, time resolution, measurement accuracy required, number of channels, etc.). But it must also include consideration of system-specific attributes. For example:

Is the instrument really programmable? A GPIB interface doesn't guarantee full programmability. Some GPIB instruments only return results — however, the front-panel settings can't be controlled. Others can be controlled but can't return answers to the controller. Some can do both. A few are actually "programmable" in the sense that they can store settings or programs locally, requiring only a press of a button or a simple command from a GPIB controller to execute a complex setup or multi-step program.

For example, all front-panel controls on the Tektronix 2400-Series analog scopes can be individually set over the GPIB, and measurement results can be returned to the controller. But the ability to store 30 front-panel setups in the scope and execute them by simple commands adds another dimension to programmability. Instead of sending complex setting strings each time a test requires a new instrument setup, a repertoire of setups can be downloaded to the instrument as part of system initialization. Then, during actual testing, single commands can recall complete setups from scope memory. This substantially reduces program complexity and bus traffic.



VOL. 12 NO. 2 SUMMER 1987

HANDSHAKE

NEWSLETTER OF INSTRUMENTATION AND INSTRUMENT SYSTEMS

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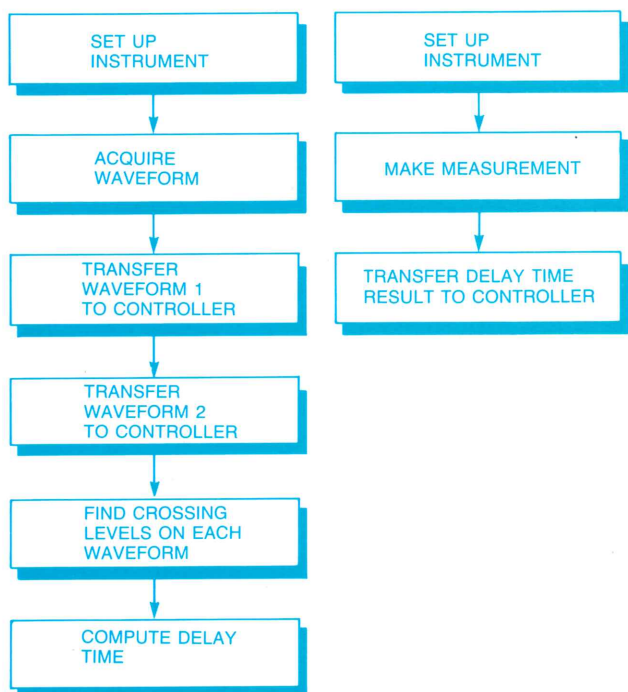


Does the instrument return answers or raw data? In most systems, the end goal is answers — a voltage or time measurement or a pass/fail judgement. These answers can be obtained by processing raw data arrays from the instrument, or the instrument can provide results directly from built-in measurement features. In some applications, the latter is preferable since it reduces software burden and increases system efficiency by eliminating bus transfers of large data arrays.

Figure 1 illustrates this further with a flowchart of a system that makes a simple time delay measurement between two waveforms. The flowchart in Figure 1A assumes that the acquiring instrument can only transfer raw waveform data. The controller calculates the delay measurement from the raw waveform data. Figure 1B shows a flowchart for the same system with the instrument making the measurement and returning the result.

Can the instrument perform multiple functions? Reducing the number of system components means simpler software, easier system configuration, and lower total system cost. Additionally, the system is more efficient since the controller spends less time setting up instruments and passing data between them.

As an example, parametric measurements (propagation delay, settling time, etc.) often must be done with an oscil-



A. Flowchart of a delay measurement calculated from raw waveform data in the system controller.

B. Flowchart of the same measurement made in the instrument with only the results transferred to the system controller.

Figure 1. Making a delay measurement by digitizing two waveforms, transferring them to the controller, and computing the delay requires more software and more time than making the measurement in the instrument and transferring only the measurement results.

loscope. However, triggering can be a problem if the function to be analyzed depends on a boolean combination or word recognition. One solution is to use a logic analyzer for word recognition to generate a trigger for the scope. A more efficient solution is a word recognizer trigger option on the scope, such as available with the Tektronix 2400-Series scopes.

What is the GPIB message format? The IEEE 488 standard does not define the syntax or coding of messages transferred across the GPIB. As a result, manufacturers choose a variety of formats for commands and data transfers. Since software is such a large part of system development costs, selecting instruments with a common message format can save many hours of program development and debugging time.

To make instruments easier to program, Tektronix developed a codes and formats standard that specifies the syntax and coding of device dependent messages while retaining full IEEE Standard 488-1978 compatibility. The **Tektronix Standard Codes and Formats** specifies message coding to:

- Be simple and unambiguous
- Use commands that are common among similar devices
- Use simple, easy-to-remember mnemonics

The benefits of the **Tektronix Standard Codes and Formats** are numerous. Because of their natural English-like structure, instrument control commands and messages are easy to use. The result is a GPIB implementation that is specifically designed to overcome the programming rigidity and cumbersome procedures of other GPIB systems.

What interface functions are implemented? IEEE 488 describes a GPIB interface in terms of ten basic functions, referred to as "interface subsets." The interface subsets for any given instrument are described by a series of mnemonics listed in the instrument specifications or printed next to the GPIB connector. Table 1 summarizes the IEEE 488 subsets. In general, the more GPIB capability provided, the more flexibility allowed in system configuration and operation.

What is the vendor's capability and reputation? A final set of questions to ask when selecting system components concerns the vendor. What capability do they provide in the way of individual instrument and system warranty, on-site service, technical assistance for interfacing and software development, documentation, repair, etc. Where is the nearest service center and what is the response time? Are their products reliable? Do they stand behind them even when out of regular production? Are replacement parts readily available and for how long? Can you call with technical questions and get results? Do they support interfacing with products from other manufacturer's? These and many other questions need to be asked in this final stage of choosing system components to be sure that you choose components that can make the measurements — next month, next year, or as long as you need to use the system.

Software makes it all work

With the instrumentation defined both in terms of measurement capability and systems compatibility, the next major step is consideration of software. Necessary software tasks include sending commands to instruments, reading responses, handling interrupt and exception conditions, processing data from instruments, and printing or logging test results. The ease and efficiency with which these tasks can be accomplished depends on the type of software selected. The software approach or software availability may also dictate controller selection.

There are at least four approaches to obtaining the required software, each with advantages and disadvantages:

1. Full custom software. Custom programming is the most expensive and time consuming approach to generating test software. Yet, it often results in the most efficient systems approach to a specific application.

Starting with an operating system and language that supports a GPIB interface driver, asynchronous interrupt processing, and high-level GPIB data transfers makes the custom programming task much easier. 4041 BASIC for the Tektronix 4041 Instrument Controller is one example of this type of language. It provides simple high-level statements for all common GPIB operations as well as support for more specialized data transfers and interface protocols. Without such language support, programming must include developing a device driver and language interface. Even with modern controller chips, writing a driver for a GPIB interface is no task for a novice.

2. Custom software based on utility packages. This approach provides a framework of general utility routines that send and receive messages, read instrument status, and perform other common GPIB functions. By using these "canned" subroutines, a custom package can be built to meet specific system requirements while avoiding many of the details of GPIB communication.

The GURU (GPIB Users Resource Utility) Package from Tektronix is one such utility package for the IBM PC. This approach eases some of the specialized programming burden for handling GPIB transactions while still providing the flexibility of a custom software package.

3. Test program generators. An even simpler approach involves using a program that writes programs — a test program generator (TPG). The user describes the tests to be performed using menus and front-panel instrument settings. The test program generator reads the front-panel settings from the instrument using a SET? query and compiles the user input into either a BASIC program or a series of data structures. The results can either be executed directly (if a BASIC program is produced) or, if the output is a file of data structures, it can be "played back" through an execute routine in the test program generator software (see Figure 2).

This is the simplest approach, requiring little or no knowledge of either the GPIB or programming. However, it usually results in slower programs which require more memory and may not offer the flexibility to handle unusual testing situations or special algorithms.

The GURU package from Tektronix includes a test program generator for general use. However, an instrument specific TPG, such as EZ-TEK 2400 PC, provides even further simplifications in setting up instrument control and measurement procedures using an IBM PC (or compatible) and any of the Tektronix 2400-Series oscilloscopes. These types of packages substantially reduce the software development burden since there is no code to write and debug. Also, because program development is so quick and easy, automation becomes attractive for a wider range of tasks, including many everyday measurements.

Another test program generator available from Tektronix is TEK EZ-TEST PC. This software package is a general purpose TPG which handles large system requirements for a wide range of instruments covering device-under-test interfaces through digital and analog stimulus and acquisition.

4. Turn-key application software. Some manufacturers offer complete software packages to perform common testing functions, such as pulse parameter analysis, etc. These packages offer a complete solution, although it is often generalized to meet the needs of a broader customer base. When such a package can be used, it is probably the fastest approach to creating a working system.

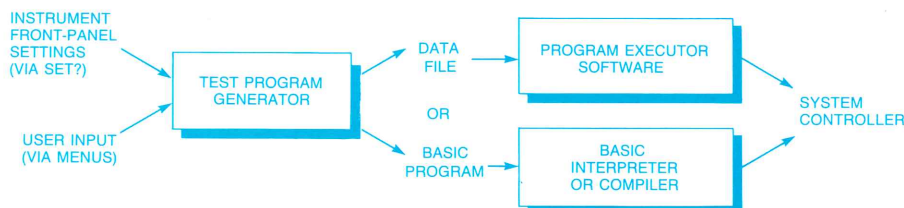


Figure 2. Flow diagram showing the typical sequence for acquiring and implementing a test with a test program generator.

Since software is such a key issue in the development of a successful GPIB system, the availability of software and the manufacturer's technical support are often as important as other specifications in choosing a GPIB instrument. Remember also, that more measurement capability built into the instruments usually translates to less software development and operating burden. The instrument does the work instead of a programmer or system operator.

Setting up the system

Choosing the system components is the first step. But the components don't form a system until they are connected

Table 1
IEEE Standard 488 Interface Subsets

SERVICE REQUEST		SR0	SR1								
Full capability	Allows an instrument to request service from the controller with the SRQ line		X								
No capability		X									
REMOTE-LOCAL		RL0	RL1	RL2							
Basic Remote-Local	Allows the instrument to switch between manual (local) control and programmable (remote) operation		X	X							
Local Lock-Out	Allows the return to local function to be disabled		X								
No capability		X									
PARALLEL POLL		PP0	PP1	PP2							
Basic Parallel Poll	Allows an instrument to report a single status bit to the controller on one of the data lines (DI01-DI08)		X	X							
Remote configuration	Allows the instrument to be configured for parallel poll by the controller		X								
No capability		X									
DEVICE CLEAR		DC0	DC1	DC2							
Basic Device Clear	Allows all instruments on the bus to be initialized to a pre-defined cleared state		X	X							
Selective Device Clear	Allows individual instruments to be cleared selectively		X								
No capability		X									
DEVICE TRIGGER		DT0	DT1								
Full capability	Allows an instrument or group of instruments to be triggered or some action started upon receipt of the Group Execute Trigger (GET) message		X								
No capability		X									
SOURCE HANDSHAKE		SH0	SH1								
Full capability	Allows a device to generate the handshake cycle for transmitting data		X								
No capability		X									
ACCEPTOR HANDSHAKE		AH0	AH1								
Full capability	Allows a device to generate the handshake for receiving data		X								
No capability		X									
TALKER (EXTENDED TALKER)*		T0 (TE0)	T1 (TE1)	T2 (TE2)	T3 (TE3)	T4 (TE4)	T5 (TE5)	T6 (TE6)	T7 (TE7)	T8 (TE8)	
Basic Talker (Basic Extended Talker)	Allows an instrument to transmit data		X	X	X	X	X	X	X	X	
Talk Only Mode	Allows an instrument to transmit data without a controller on the bus		X		X		X		X		
Unaddressed If My Listen Address (MLA)	Prevents an instrument from being a talker and a listener at the same time						X	X	X	X	
Serial Poll	Allows an instrument to send a status byte in response to a serial poll		X	X			X	X			
No capability		X									
LISTENER (EXTENDED LISTENER)*		L0 (LE0)	L1 (LE1)	L2 (LE2)	L3 (LE3)	L4 (LE4)					
Basic Listener (Basic Extended Listener)	Allows an instrument to receive data		X	X	X	X					
Listen Only Mode	Allows an instrument to receive data without a controller on the bus		X		X						
Unaddress If My Talk Address (MTA)	Prevents an instrument from being a talker and a listener at the same time				X	X					
No capability		X									

* Extended talkers and listeners use secondary addresses; other talkers and listeners do not.

Putting GPIB systems to work ...

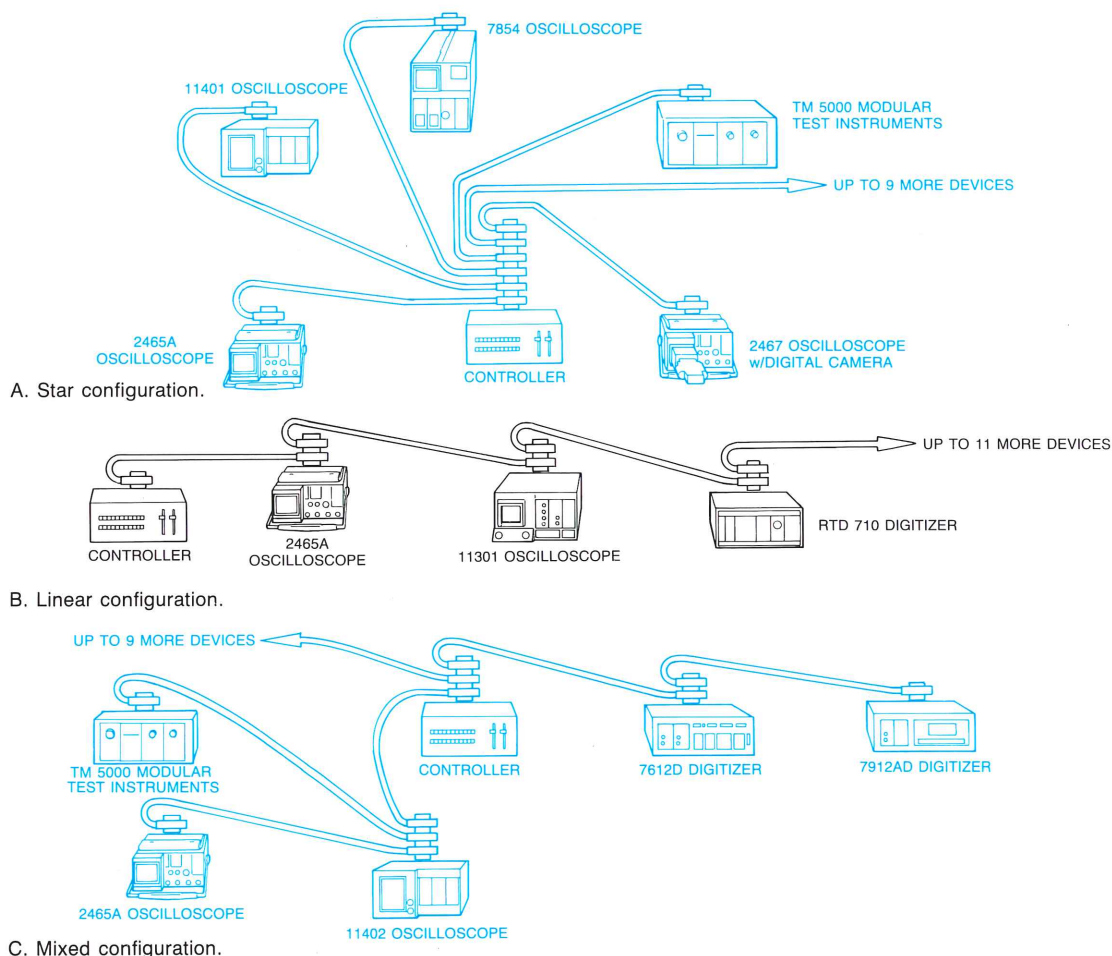


Figure 3. Up to 15 devices may be cabled to a single GPIB bus in a star, linear, or mixed arrangement.

together and configured to operate in an orderly fashion. Fortunately, the connection and configuration process is relatively simple, consisting of five basic steps.

1. Cable the system components together. The instruments and controller can be cabled in a star or linear fashion, or a combination of the two (see Figure 3). Up to 15 devices, including the controller, can be connected to the bus. If the controller supports two or more busses, each bus can have up to 15 devices, including the controller. Some plug-in devices may represent more than one load, so check the instrument manual for details.

One device must be connected to the bus for each two meters of cable, and the total length of all cable used must not be more than 20 meters. Devices may either be lumped at the cable ends or distributed along the cable.

2. Set the device addresses. Each device in the system must have a unique primary address from 0 to 30. Addresses may be selected by rear-panel switches or through front-panel menus and controls. Remember that the controller may also require an address. Setting a device to address 31 logically removes it from the bus, though it still represents one device load.

Some instruments may also require a secondary address to select plug-ins or other functions. Secondary addresses may be duplicated among devices with different primary addresses. Again, the manuals are the best source of specific information for a particular instrument.

3. Set the GPIB mode. In many instruments three modes are available: Talk/listen, talk only, and listen only. Talk/listen is the normal mode for operation with a controller (see the sidebar **GPIB Controller orchestrates system activity**). Talk-only and listen-only modes are used for transferring data between devices without a controller. For example, the Tektronix 2400-Series DMM option in talk-only mode can transfer stored readings to a printer set for listen-only mode. For operation with a controller, the 2400-Series scopes are set to the appropriate talk/listen mode by the XFER function used.

4. Set the message terminator. Two options are usually provided — EOI or Line-Feed. For Tektronix instruments and controllers, EOI is the preferred terminator, though a line-feed terminator mode is provided for compatibility with other instruments and controllers. For most applications, either setting may be used as long as all devices use the same terminator.

GPIB controller orchestrates system activity

The controller in a GPIB system is like the conductor in an orchestra — it keeps everybody playing together. In this case, the “musicians” are the instruments and peripherals that make up the GPIB system, and the musical score is the program the controller follows to get the job done.

Getting the message across

The controller directs system activity using two types of messages. The first type is the “interface” message. These messages, defined by IEEE Standard 488, control the interface or perform common system functions, such as addressing instruments. For example, the controller sends addresses (classed as interface messages) to set up a transfer between two devices on the bus. Device Clear (DCL) is an example of an interface message. It tells all instruments on the bus to go to an initialized state.

The second message type is the “device-dependent” message. These messages consist of commands or data that are defined by the instrument manufacturer. They are unique to the instrument type and are not defined by IEEE Standard 488.

The controller identifies devices involved as talkers (sending data) or listeners (receiving data) in any bus transaction by addressing them. Each device on the bus has a unique primary address that actually represents two unique addresses — a talk address and a listen address. In a typical message transfer, the controller addresses one device to talk and one or more to listen. Devices that are not addressed do not participate in the transfer.

Once the addressing sequence is complete, the talker begins sending its data, waiting after each byte for a ready signal from the listener before continuing to the next byte. The message transfer continues until the pre-defined message terminator (EOI bus signal or line feed character) is

sent. Then, the controller unaddresses the instruments and is free to set up a new transfer.

The process is similar for getting a response from an instrument. Generally, the controller sends a “query” command that tells the instrument to prepare to send the desired information. Then, the controller addresses the instrument to talk and conditions itself to listen. The instrument returns the requested information with the appropriate message terminator. The controller finishes the cycle by unaddressing itself and the instrument.

SRQs signal special conditions

On occasion, devices in the system may have a special reason to request the controller’s attention. For example, an error may have occurred in processing the last command, or an overload condition may occur on an input. An instrument with the Service Request function (subset SR1) can request the controller’s attention at any time using the Service Request (SRQ) bus signal.

The SRQ signal tells the controller to temporarily interrupt its current processing task, handle the special condition, and return to where it left off in its previous task. However, SRQ handling is highly dependent on the software running in the controller. In some of the more sophisticated implementations of BASIC, for example, all the programmer has to do is write a routine to handle the SRQ conditions and insert a statement that tells the controller where this special SRQ routine begins. When an SRQ occurs, the operating system automatically interrupts normal program flow and begins the SRQ processing routine. When the SRQ routine is finished, processing resumes from where it was interrupted.

Unfortunately, less sophisticated languages don’t have this interrupt


capability. Some “work-around” solutions are available, but they aren’t as convenient or efficient as the more powerful interrupt-structured languages designed for instrument control.

Finding the interrupt source

Even when the controller recognizes the existence of an SRQ, it still can’t be sure which instrument generated the interrupt in a multiple-instrument system since all devices on the bus share the SRQ line. The controller finds the interrupting device by “polling” each device. When an instrument is polled, it sends a single 8-bit byte of status information to the controller to indicate its status. IEEE 488 specifies bit 7 as the indicator of whether a device is asserting SRQ or not. If bit 7 is set (1), the device is asserting SRQ. If bit 7 is clear (0), the device is not asserting SRQ.

The remainder of the status byte is not defined by IEEE 488. However, the **Tektronix Standard Codes and Formats** defines the status byte to make status handling for all Tektronix GPIB instruments common and simple. The controller can even find out more detailed information about the instrument’s condition using a common EVENT? query — also defined by the **Tektronix Standard Codes and Formats**.

Software implements the protocols

Fortunately, most of the protocol details of sending and receiving messages and handling interrupt conditions are handled by high-level language statements in many controllers. The key to implementing GPIB system software is to use a powerful language that supports high-level GPIB interaction. This frees the programmer to concentrate on the test at hand and reduces the need for a detailed understanding of GPIB protocols. 

Putting GPIB systems to work ...

For binary data transfers, EOI should be used since normal binary data may contain line feed characters.

5. Power up the system (if not already on). Some instruments require that power be cycled after GPIB address or mode changes to make the new settings effective. For reliable bus operation, at least two-thirds of the devices on the bus must be powered up, whether they are used or not.

Faster is better

A properly configured system with carefully chosen components and well-designed software usually meets its performance goals. However, even when you carefully follow all these system-development guidelines, there's still room for improvement. Once the system is in use, areas of needed performance improvement will become apparent. Some common approaches to improving performance are listed below.

- **Reduce instrument setup time.** Group tests that use common settings to reduce the time it takes the controller to make the required setting changes. Setup time can also be dramatically reduced by pre-loading setups into an instrument if the instrument can store multiple setups.
- **Reduce data acquisition time.** Acquire and communicate only the end results to reduce the time required to transfer complete waveforms. After a test has been set up visually, it's often not necessary to digitize an entire waveform. A counter/timer, for example, can make many timing measurements without acquiring waveform data.
- **Use automatic setup features.** Some instruments can characterize unknown signals quickly through the use of an automatic setup feature. Otherwise, the operator (or software) may spend significant time "hunting" with the vertical and horizontal controls to find the signal.
- **Keep operator interaction simple.** Instead of printing prompt messages or instructions on the computer screen, consider displaying prompts directly on the front panel or CRT of the test instrument. Keeping user attention in one place makes the human interface simpler and more efficient.
- **Use the operator's visual judgement skills.** While a controller can quickly calculate results and keep flawless records,

human operators can often spot out-of-limit waveforms or other anomalies quicker than a controller can transfer and analyze waveform data.

These are just a few suggestions. But they are key points to start with and often lead to further performance improvements.

To automate or not to automate

Automation still isn't the answer in every test situation. But as instrument power increases and lower-cost controllers and software become available, automation is more attractive than ever before. The simple guidelines discussed here provide a solid basis for evaluating the feasibility of automating a particular test application. If automation is warranted, these guidelines can also help implement a system that does what automation is intended to do — reduce costs and improve performance.

For further information or assistance in evaluating automation of your measurement procedure, contact your local Tektronix Field Office or representative.

Other references

Several articles have appeared in recent issues of **HANDSHAKE** which use the GPIB as a basis of system configuration. Refer to these articles for additional information.


"Digital oscilloscope teamed with mini for neurophysiology system." **HANDSHAKE**, Summer 1985, Page 12.

"Digital pulse-echo techniques for advanced composites." **HANDSHAKE**, Spring 1986, page 10.

"Making automated TDR measurements." **HANDSHAKE**, Summer 1986, Page 11.

"Putting ASYST to work ... Engine performance measurements." **HANDSHAKE**, Fall 1986, Page 22.

"Zero defects through automatic ultrasonic testing of nodular iron castings." **HANDSHAKE**, Winter 1986-87, page 27.

For copies of any of these back issues of **HANDSHAKE**, contact your local Tektronix Field Office or write to the **HANDSHAKE** Group. 

How to computerize your measurements without compromising results.

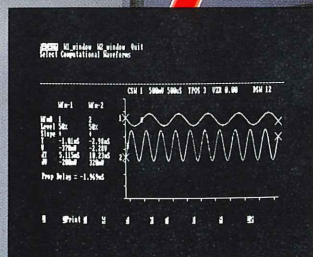
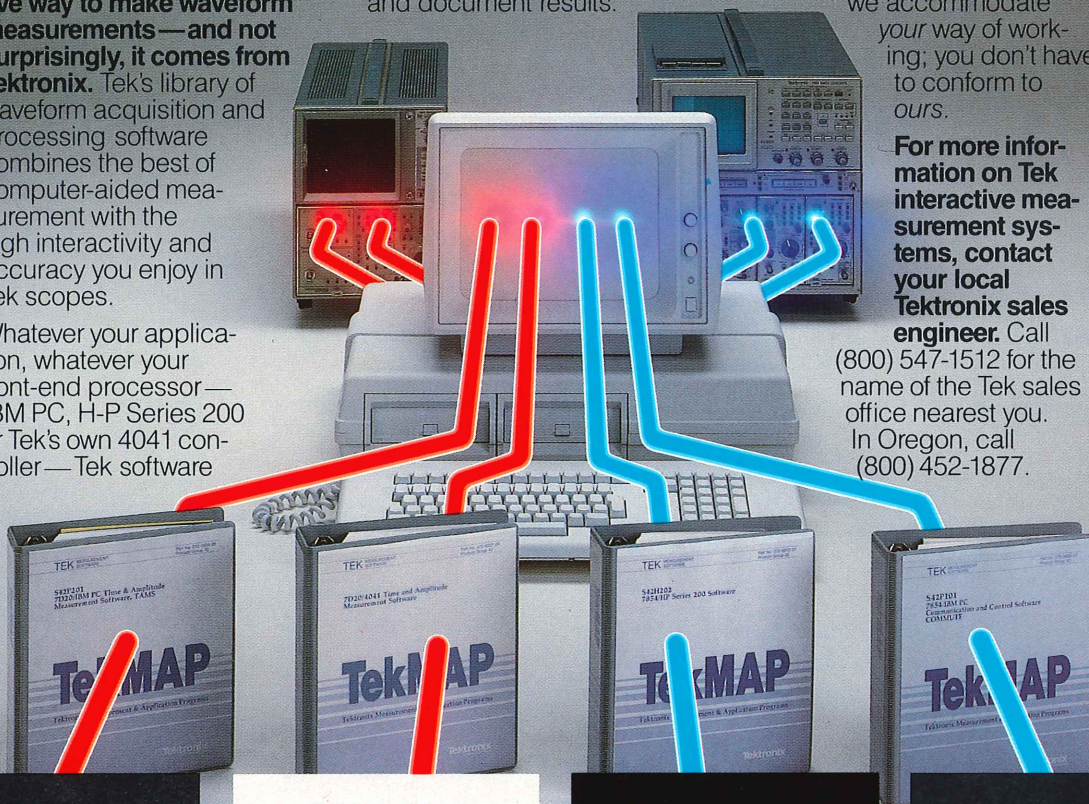
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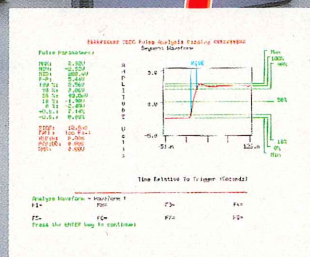
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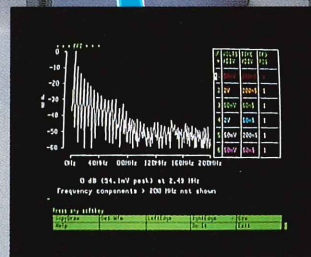
For more information on Tek interactive measurement systems, contact your local Tektronix sales engineer. Call (800) 547-1512 for the name of the Tek sales office nearest you. In Oregon, call (800) 452-1877.



Delay time measurement using an IBM PC/XT/AT as controller with Tek's Time and Amplitude Measurement Software. Instruments: the Tek 7D20 Programmable Digitizer and Tek 7603 oscilloscope.



Automated pulse parameter analysis using a Tek 4041 Controller and Tek Time and Amplitude Measurement Software to direct the efforts of the 7D20 in a 7603 mainframe. Hard copy generated by a Tek 4695 Color Copier.



Computing and displaying frequency domain data (FFT), using an HP Series 200 Technical Computer as controller. Tek software for these results accommodates the HP Series 200 with the Tek 7D20 or the Tek 7854 Waveform Processing Oscilloscope.



Editing a Tek 7854 RPN program, including comments, for downloading to the 7854 or archiving to disk. Performed with the HP 200 Series Technical Computer, the Tek 7854, and Tek 7854/HP Series 200 Software. Similar facility available in COMMUTE.

Customer training classes and workshops

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.

Service Training Classes

Call Tektronix Service Training, 1-800-835-9433, ext WR1407 (in Oregon, call 629-1407) to register for the following classes.

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465B/475A Portable Oscilloscope	Atlanta Irvine	Oct 12-16 Feb 15-19
2215/35/36 Portable Oscilloscope	Boston Irvine	Oct 26-30 Jan 25-29
2430 Digital Storage Oscilloscope	Dallas	Feb 22-Mar 4
2465A Portable Oscilloscope	Boston Dallas	Nov 9-20 Mar 21-Apr 1
7904/7633 Laboratory Storage Oscilloscopes	Atlanta Boston	Dec 7-18 Mar 21-Apr 1
7912AD Programmable Digitizer	Beaverton	Oct 26-Nov 6
TM 5000 Programmable Instruments	Beaverton	Call for schedule

In addition to classroom instruction, Tektronix Service Training has a variety of training packages and videotapes 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. 

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Call Tektronix IG Customer Training, 1-800-835-9433, ext 430 (in Oregon, call 629-1017) to register for the following classes.

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XYZ's of Using a Scope	Columbus	Oct 14
High Speed Measurements Using Sampling Techniques	Woodbridge	Sep 24
Using a 4041 System Controller	Lexington	Oct 13-15
Using the PC as a Controller	Lexington Philadelphia	Sep 18 Sep 23
7912AD/7612D Advanced Waveform Processing with TEK SPS BASIC	Beaverton	Oct 26-29
2230 Digital Storage Measurements	Lexington Philadelphia	Sep 15 Oct 20
2430A Advanced Digital Measurements	Lexington Philadelphia Indianapolis	Sep 16-17 Oct 21-22 Nov 4-5
7854 Waveform Processing	Woodbridge Philadelphia	Sep 22-23 Nov 11-12
11301/11302 Measurement and Analysis	Lexington Orlando San Diego Dayton	Sep 23 Oct 8 Oct 22 Nov 19
11301/11302 Advanced Measurement and Analysis	San Diego Dayton	Oct 22-23 Nov 19-20
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