TEK APPLICATION INFORMATION

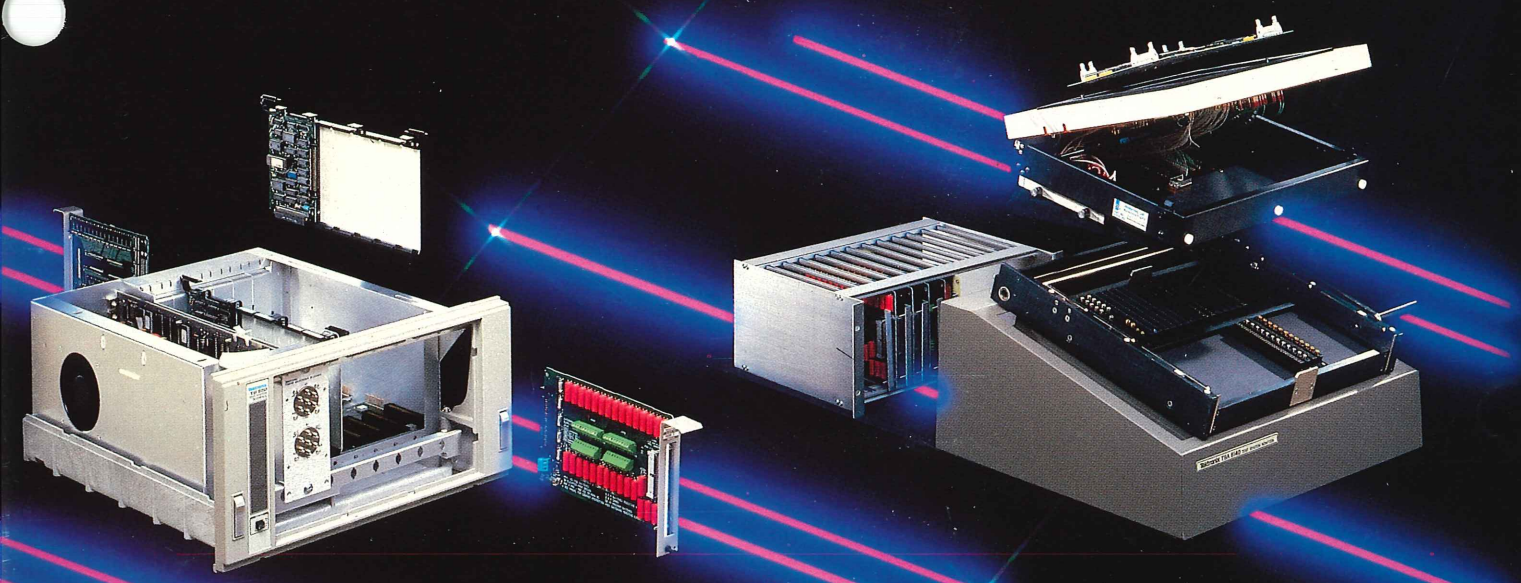
VOL. 11 NO. 2
SUMMER 1986

HANDSHAKE

NEWSLETTER OF SIGNAL PROCESSING AND INSTRUMENT CONTROL

TSI 8150

THE MISSING LINK IN ATE



Tektronix®
COMMITTED TO EXCELLENCE

Table of contents

Return the reply card in this issue for a free subscription to HANDSHAKE

Editor: A. Dale Aufrecht
Graphic Designer: Joann Crook
Production Editor: Anita Hicks
Printer: Dynagraphics, Inc.

FOR MORE INFORMATION: Readers in the United States can use the postpaid reply card in this issue for a free subscription to **HANDSHAKE** or to request more information. International readers please contact the Tektronix Sales Representative for your country. If you need to find the address of your representative, contact a Tektronix area office:

Asia, Central and South America
Tektronix, Inc.
Americas Pacific U.S. Export Sales
P.O. Box 500, MS 51-297
Beaverton, OR 97077
U.S.A.
Phone: 503-643-8868
Telex: 4742103 TekWSGT

Eastern Europe
Tektronix Ges.m.b.H
Doerenkampgasse 7
A-1100 Vienna
Austria
Phone: 43 (222) 68-66-02
Telex: (847) 111481 TEK A

Africa, Middle East and Western Europe
Tektronix Limited
P.O. Box 36
Guernsey, Channel Islands
Phone: 44 (481) 711211, 35781
Telex: (851) 4191193 TEKGNY G

A look inside

An often overlooked aspect of test system design is the interface to the device-under-test (DUT). New technologies and new instruments usually focus on faster, more accurate measurements. But until you can get access to the device-under-test in a way that both provides signal routing and preserves signal integrity, these measurement advancements are of little value. For today's ATE systems, there is a missing link — a product to provide both complete automated signal routing and a physical interface between the automated test instruments and the devices being tested.

Enter the new Tektronix TSI 8150 Test System Interface! This new product from the Instrument Systems Integration Division of Tektronix is specifically designed to provide a complete interfacing solution, maintain signal integrity, and maximize system throughput. You'll find a complete description of this exciting new product in the articles entitled **"Introducing TSI — a family solution to test system interfacing"** and **"DUT adapter speeds test setup changes."**

The TSI 8150 Test System Interface also plays a role in the application article **"Making automated TDR measurements."** This article describes the technique for using the 7854 Waveform Processing Oscilloscope with a 7S12 Sampler to perform TDR measurements.

"Ultrasonic characterization of microstructure" provides another chapter on non-destructive testing. L.P. Scudder and R.L. Smith of the Harwell NDT Centre, Oxfordshire, United Kingdom provide some insights into materials characterization using a signal processing system.

Several new product introductions and information on available article reprints fill out this issue.

We hope you enjoy reading this issue of **HANDSHAKE** and that it helps solve your signal processing problems. For more information on any of the products described in this issue or for help with your signal measurement needs, contact your local Tektronix Sales Engineer or the Tektronix Sales Representative for your country. And be sure to tell them you saw it in **HANDSHAKE!**

A. Dale Aufrecht
HANDSHAKE Editor

Introducing TSI — a family solution to test system interfacing

Dave Barnard
Instrument Systems Integration Marketing
Tektronix, Inc.

When assembling an ATE system, today's system builders must solve a series of problems. What programmable measurement instruments provide the highest performance at the lowest cost? What system controller provides the most efficient control of a variety of measurement instruments and accessories? What software will run the system? And — most difficult — how can all these units be tied together quickly, effectively, and inexpensively?

Today's programmable measurement instruments offer high levels of performance for all specifications. A variety of system controllers dedicated to instrument control are available. The weakest link is the interface between the device-under-test (DUT) and the many instruments and accessories required in test systems.

Until now, test system interfaces have required expensive, time-consuming custom solutions to solve mechanical and electrical interface problems. These problems include:

- Need for a complete switching solution.
- Maximum system throughput.
- Preserving signal integrity.
- Providing a physical interface between the measurement instruments and the DUT that is flexible to begin with yet easy to reconfigure when test needs change.
- Easy operation over the GPIB without burdening the system controller with management of switching tasks.

Complete solution now available

Now an inexpensive and easy-to-implement solution is available. The Tektronix Test System Interface (TSI) family (see Figure 1) provides the first commercially available, flexible, and complete link between measurement instruments and the DUT.

The TSI family offers a complete test system interface solution by integrating these features:

- Scanning control.
- Physical connections between instruments and the DUT.
- System timing control.
- Both digital and analog signal routing for a wide range of signal types, bandwidths, and amplitudes.

The heart of the TSI family is the TSI 8150 Test System Interface mainframe (see Figure 2). The TSI 8150 is an intelligent, highly configurable mainframe that houses scanner control cards and accepts a variety of switch assemblies to maximize switching and signal routing choices. The switch assemblies currently available, including cards for low-frequency applications and switch modules for high-frequency applications, are shown in the sidebar **TSI Switch Assemblies.**

The TSS40 Scanner Control Assembly simplifies the system builder's task by furnishing an intelligent interface between the TSI 8150 mainframe and any TSI switch assembly. Figure 3

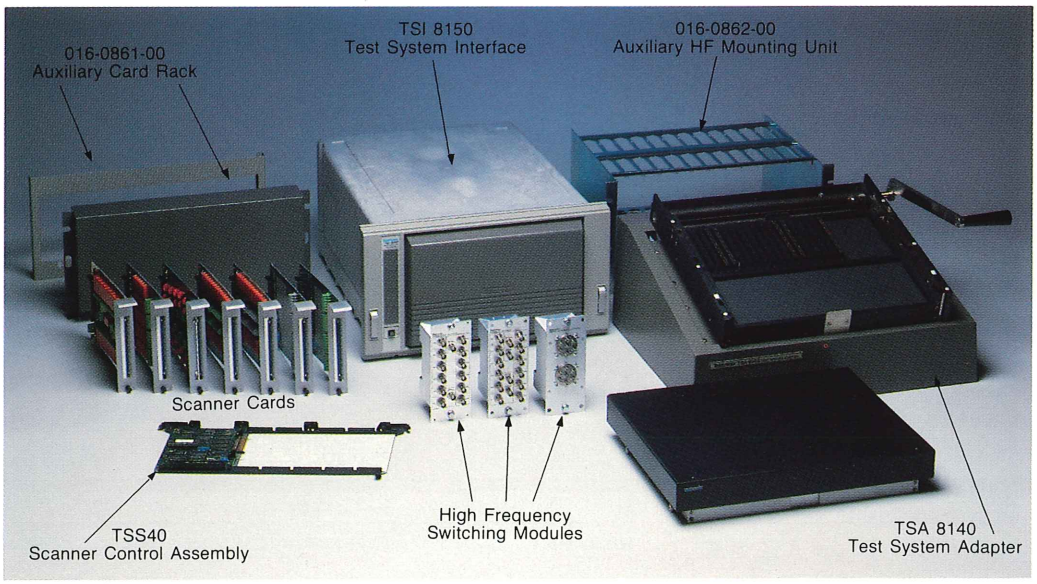


Figure 1. *The Tektronix TSI 8150 Test System Interface family provides a complete switching and physical interface solution for ATE systems.*

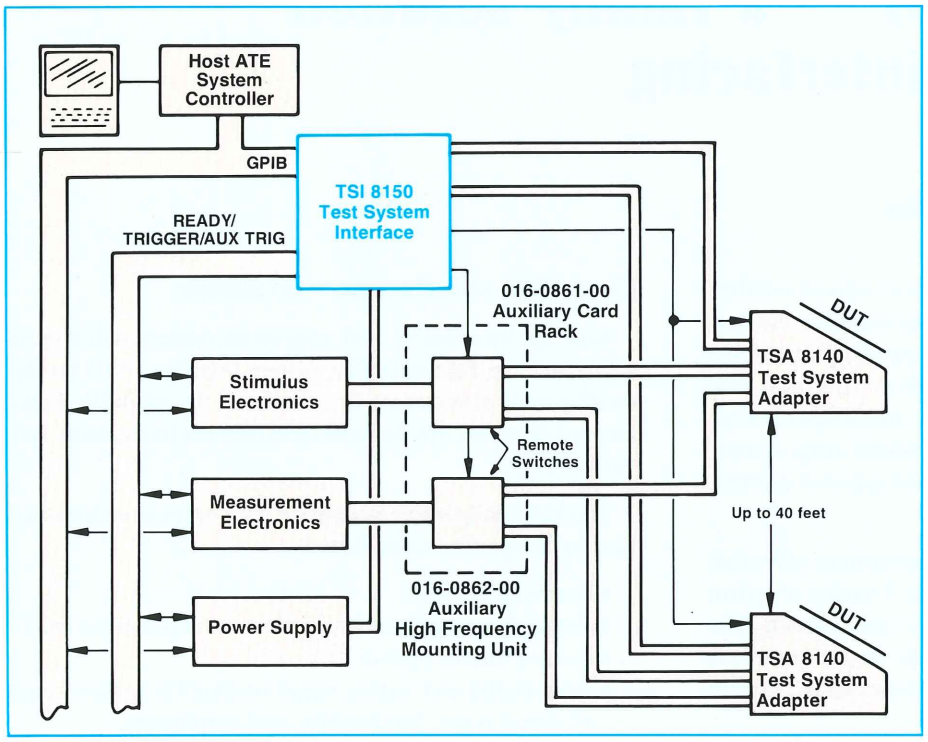


Figure 2. *The TSI family completes an automatic test system by providing the interface between the ATE system controller, measurement instruments, and the DUT.*

illustrates the chain of control in a typical system. Each TSS40 can control a single switch card or up to two switch modules.

Each TSS40 can store up to 500 test steps sent over the GPIB from the system controller. Then, under either trigger-line or GPIB command control, local intelligence in the TSS40 can control the test sequence of up to 32 switches. The switches may be programmed in either make-before-break (MBB) or break-before-make (BBM) configuration to allow the switching action which best fits each specific application.

Flexible, easy-to-reconfigure interfacing

With suitable options, the TSI 8150 Test System Interface simplifies test system configuration by providing connections to the switch assemblies from the front of the mainframe, from the back, or both. A dedicated cableway, about 1⅞ inches high by 7¾ inches wide, runs front to back through the bottom of the TSI 8150 mainframe. This allows the user to route cables in either direction, out of sight and in a shielded, protected environment.

The TSI 8150 mainframe can hold up to nine TSS40s and switch assemblies. In addition, switch assemblies may be remotely mounted either in the TSA 8140 DUT Adapter (discussed in the following article) or they may be rack-mounted in auxiliary mounting units anywhere in the system up to a maximum of 40 feet away from the TSI 8150 mainframe. The TSS40 itself always resides in the TSI 8150 mainframe.

Preserving signal integrity

To make sure the test system is measuring characteristics of the DUT — not the system itself — the interface must be free of interference, crosstalk, or other signal degradation. The TSI has designed-in features to ensure signal integrity such

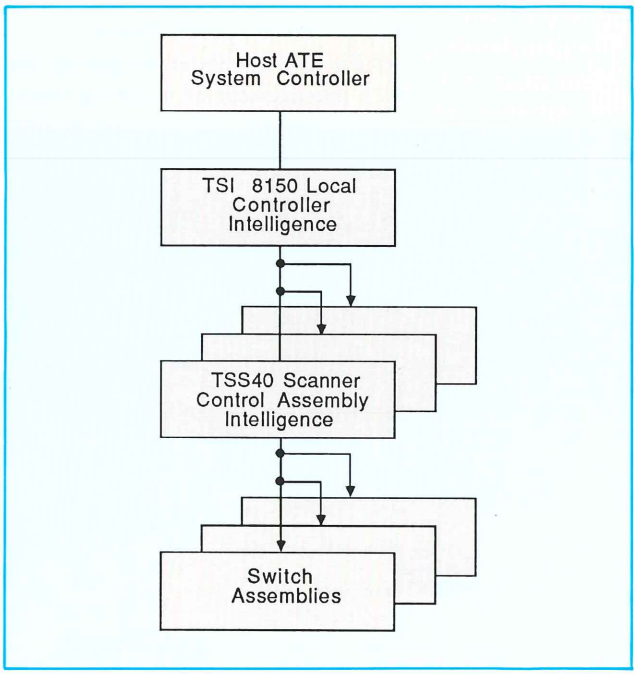


Figure 3. *TSI 8150 chain of intelligence and control.*

Special design features answer special needs

Based on extensive market research, the TSI design team added many special features to the TSI family of products. A few of these features are:

- **Ground lug and system grounding** reduces ground loops and minimizes ESD (electrostatic discharge) problems.
- **Mercury-wetted switches** provide long-life switching and consistent channel resistance over the life of the switch.
- **Make-before-break and break-before-make** switch control capability gives system builders versatility in setting switch configurations.
- **Built-in trigger system** provides hardware control of instruments and allows the system builder to create an asynchronous interface to the TSI 8150 mainframe.
- **Open all switches** software command allows the user to setup a "warm reset" without changing stored switch sequences.
- **Coil-voltage detection circuit** on every scanner card generates an error if a switch is told to close but not enough coil voltage is available.
- **XEQ synch (execution synch)** triggers all cards to change switch states at the same time.

as linear power supplies, shielded switch assemblies, minimized bus activity, and remote switch mounting for reduced signal path lengths.

The TSI 8150 mainframe uses a linear power supply to avoid the high-frequency noise problems usually associated with switching supplies. This keeps the entire test system free from switching noise — particularly important when dealing with low-level signals.

As would be expected, the high-frequency switch modules have integral metal shielding. However in theTSI family, even the low-frequency switch cards are shielded when they are mounted in the TSI 8150 mainframe. Each switch card is inserted into a frame that contains both the TSS40 Scanner Control Assembly and slide rails for the switch card (see Figure 4). This frame includes shielding for the assembly.

Shielding is especially important in large test setups. Here the user might switch high-power inductive loads on one card and low-level (down to one microvolt) differential offset signals on the adjacent card. Ability to mix different kinds of switching is one of the many advantages of the TSI family interface solution.

An additional approach to keeping the system quiet during measurements is reducing bus traffic. The key step in this approach is local storage of test sequences, passed from the system controller to the TSI 8150 mainframe under control of the TSI 8150 local intelligence.

The ability to remotely locate switches reduces signal path lengths and thereby maintains signal integrity. Locating switches near the DUT and the measurement instruments reduces transmission line reflections at higher frequencies. For example, at 18 GHz, every additional eight inches of cable between the switch and the DUT produces an insertion loss equal to the loss produced by the switch itself.

Maximizing system throughput

Test-sequence storage and real-time execution capability maximizes system throughput. Only the switch settling time significantly limits operating speed. Tests are not slowed by bus communication or controller processing.

Consider a system in which the interface unit scans the outputs of several hundred sensors and the output passes to a DMM (digital multimeter). The DMM interrupts the controller when a measurement is out of range.

The interface unit — rather than the controller — scans all instruments unless there is an interrupt. If there are no interrupts, the controller begins to acquire data. Only if a measurement value is out of range will the controller become active again to scan the signal channels to find the one that is out of range.

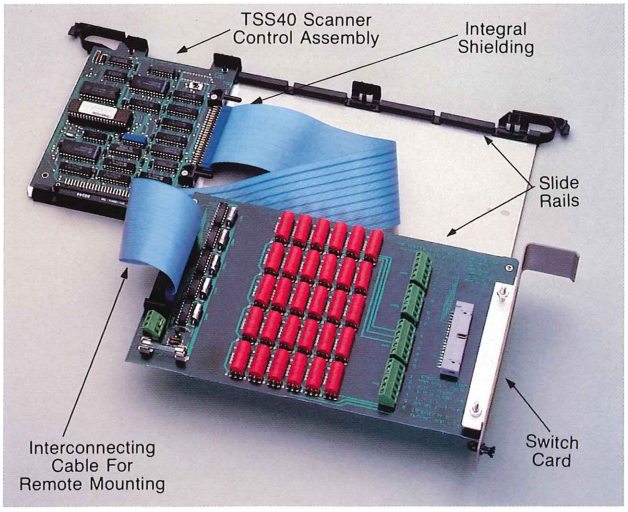


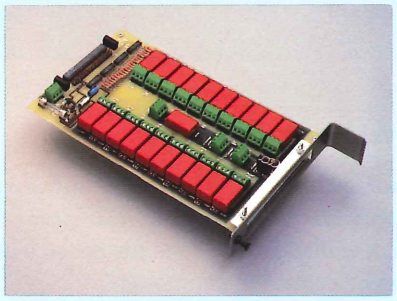
Figure 4. *Switch cards slide into TSS40 Scanner Control Assembly frame which includes an integral shield.*

Handling scanning in the interface unit cuts controller activity and bus traffic. This reduced controller and bus activity increases system throughput and signal integrity.

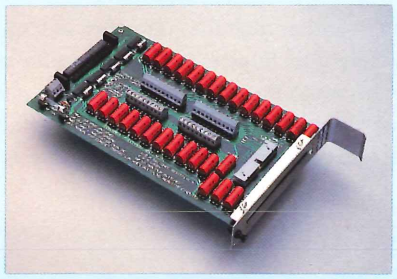
Another feature of the TSI family that maximizes system throughput is the TSI 8150's local break-before-make and make-before-break switch setting capability. Local control

TSI switch assemblies

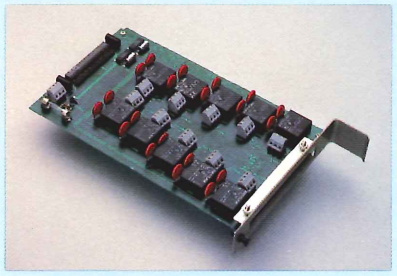
The TSI family of plug-in switch cards and modules spans frequencies from DC to 18 GHz and offers switching trees in a variety of configurations. The following switch assemblies are currently available.



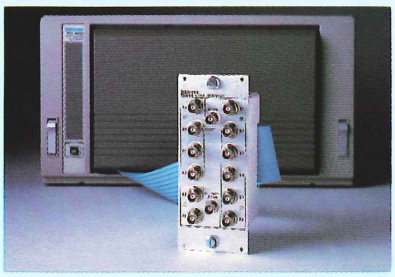
TSS41 Low Level Scanner Card.
Multiplexes signals as small as 1 microvolt (option 01) in two 1x10 trees or one 1x20 tree.



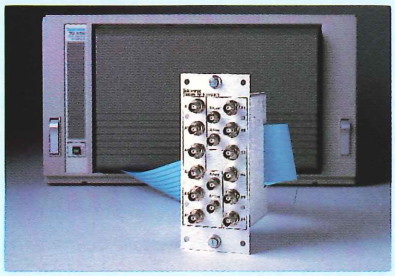
TSS42 General Purpose Scanner Card.
Provides switch trees for 30 channels and a wide range of current and voltage.



TSS43 Power Switch Card.
Provides 10 power channels, up to 10 Amps DC and 150 peak AC.

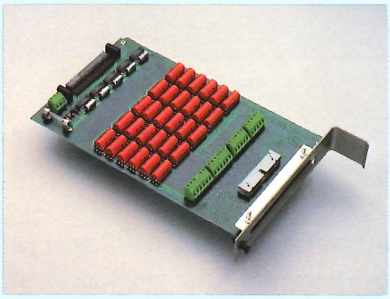


TSS44 Coax Scanner Module.
Multiplexes moderate bandwidth signals, in two 1x6 switch trees.

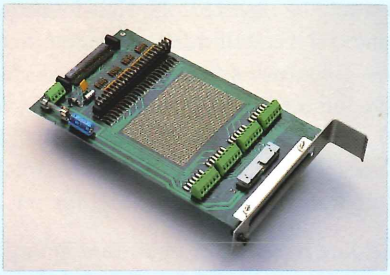


TSS45 RF Scanner Module.
Multiplexes RF bandwidth signals.

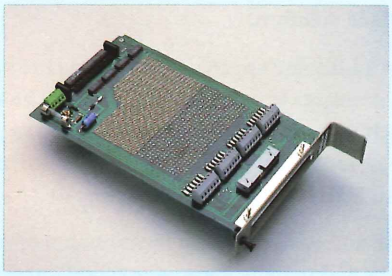
TSS46 Microwave Scanner Module.
Multiplexes DC to 18 GHz signals.



TSS48 Matrix Switch Card.
Provides a matrix arrangement for 30 switch channels.



021-0417-00 60 Milliamp Driver Card.
Provides customizing capability; control for 24 user-supplied switches.



021-0418-00 High-Current Driver Card.
Provides customizing capability; control for 24 user-supplied switches.

minimizes the amount of controller time and communication required to set up the switches.

Also, TSI 8150 internal triggering capability enhances throughput by signaling test sequence completion before starting another sequence.

Cutting system development costs

A variety of design features cut the time required to interface system components, operate the system, and maintain it.

Selecting from a family of compatible, commercially available products cuts costs in two ways. First, the interface

TSI family commands

The following list provides an overview of the TSI family programming commands. This is not intended as a programming guide but, instead, to give an idea of the programming power available.

Local controller system commands

AUXSEL	Connect AUX input to a trigger line.
AUXSEL?	Report auxiliary input status.
DT	Device trigger control.
DT?	Report state of device trigger.
ERROR?	Report detected errors.
EVENT?	Report events.
HELP?	Recall command list.
ID?	Report system identity.
INIT	Initialize TSI 8150.
LLSET	Send hardware settings.
LLSET?	Report low-level settings in binary block format.
LLSIZE?	Return size of LLSET? response.
OPENALL	Open all scanner card switches.
RQS	Enable sending SRQ on GPIB.
RQS?	Report status of SRQ function.
RUN	Set/Stop line to Run state.
RUN?	Report/Stop line state.
SET?	Report entire system settings.
SSIZE?	Report size of SET? response.
STOP	Set/Stop line to stop state.
TDISP	Display trigger line activity.
TDISP?	Report trigger to front-panel connection.
TEST?	Initiate a system hardware test.
TINT	Enable trigger line interrupt.
TINT?	Report trigger line status.
TRIG?	Report trigger bus configuration.

Local controller pulse generator commands

GENERATOR	Start or stop pulse generator.
GENERATOR?	Report pulse generator status.
GSET	Set pulse generator parameters.
GSET?	Report pulse generator status.
SSHOT	Pulse one or more trigger lines.

Local controller counter commands

CLOAD	Preload counter.
COUNT	Start or stop counter.
COUNT?	Report counter status.
CRESET	Reset counter.
CSEND	Send counter result.
CTRIG	Set counter triggers to increment or decrement.
CTRIG?	Report counter trigger argument list.

Scanner card switch commands

CLOSE	Close specified switches.
CLOSE?	Report closed switches.
NEXT	Step to next switch setting.
OCLOSE	Close specified switches and open all others.
OCLOSE?	Report closed switches.
OPEN	Open specified switches.
OPEN?	Report open switches.
WORD	Write hexadecimal output word.
WORD?	Report contents of output latch.

Scanner card setup commands

BBM	Set switches to break-before-make timing.
BBM?	Report state of break-before-make switches.
BKPT	Stop a sequence execution on specified step.
BKPT?	Report last break point set.
CONFIGURE?	Report switch configuration.
ITRIGGER	Select input trigger source.
ITRIGGER?	Report trigger selection.
LBSIZE?	Return size of LBUF? response.
LBUF	Send sequence buffer contents.
LBUF?	Report sequence buffer settings in binary block format.
MBB	Set switches to make-before-break timing.
MBB?	Report state of make-before-break switches.
READY	Enable ready reporting.
READY?	Report ready function status.
SEQDN	Enable sequence done reporting.
SEQDN?	Report sequence done flag status.
STLTIME	Specify settling time.
STLTIME?	Report current settling time.
TYPE?	Report scanner card type.

Scanner card mode commands

CONTINUE	Continue from a breakpoint.
EDIT	Edit the sequence buffer.
EDIT?	Report editing mode.
MODE?	Report scanner card mode.
SCAN	Enter scan mode.
SCAN?	Report scan sequence.
SEQUENCE	Enter sequence mode.
SEQUENCE?	Report sequence setup.

Scanner card edit sequence buffer commands

ADD	Add switch closures to sequence buffer step.
DELETE	Delete a sequence step.
DUPLICATE	Duplicate a sequence step.
LOOK?	Examine a sequence step.
POINT	Point sequence buffer cursor.
POINT?	Report pointed sequence buffer step number.
REMOVE	Remove switch closures from sequence buffer.
SEQBUF?	Report number of steps used.

units themselves are less expensive than customized units. Secondly, integrating them into the test system is much faster, thereby reducing labor costs.

Mechanical flexibility simplifies the system integration process. Front and rear access, combined with remote switch mounting, provides flexibility of configuration for special setups. The TSI 8150 cableway, large enough to accept half a dozen or more cables, also adds configuration flexibility.

TSI software

Once the system is assembled, the system builder's next task is developing test programs. Software is available to allow the test system builder to start a step up from programming languages. For example, a software front-panel program is available for use with the 4041 System Controller that includes a routine to store switch sequences in disk files. Another provides a sequence editor to edit or create sequences stored in the TSS40 Scanner Control Assembly.

TSI control commands conform to the simple, English-like Tektronix Standard Codes and Formats guidelines. This means easy-to-remember, straight-forward commands. Each command performs a function, such as opening or closing a specific switch, opening or closing all switches, or opening or closing a combination of switches.

Consider, for example, the command MBB.F1 A1...A4. This simple command sets switches A1, A2, A3, and A4 on the first front switch assembly, to make-before-break mode.

A second example is OCLOSE.F2 A3. This command closes switch A3 on the second front switch assembly and opens all other contacts.

A third example is OPENALL. This command opens all switches — a useful software panic button. It can also serve as a "warm reset" without clearing sequence buffers.

Commands available to control the TSI family allow versatility in designing test programs. The sidebar **TSI family commands** provides a brief overview of the available commands.

A system for the long run

An interface system designed for modularity allows the system builder to easily replace cards and modules as new system applications develop. It also provides an easy upgrading path for additional cards and modules as test needs change.

With the TSI family, maintenance is much less expensive because spares are readily available and documentation is thorough. Tektronix offers service around the world with a variety of service agreements available. In addition, Tektronix makes a commitment to support its products long-term.

Tektronix provides training in the operation, programming, and maintenance of many of our products. Or if you need assistance in any aspect of system development — problem definition, hardware integration, system installation, or user training — skilled Tektronix Applications Engineers are available to assist you. Contact your local Tektronix Field Office or Tektronix Sales Representative for information on Tektronix system support.

Physical interfacing

The TSI family also answers the last requirement for complete interfacing — making convenient and flexible physical connections between the DUT and measurement instruments. The TSA 8140 Test System Adapter accepts switch cards and modules for close connections to the DUT, offers a patch panel for customized connections, presents removable top panels for easy exchange of adapter fixtures, and provides connections for fixtures provided by other companies.

The following article, **DUT adapter speeds test setup changes,** explores the many interfacing possibilities of the TSA 8140 Test System Adapter.

Conclusion

This article only provides a brief overview of how the TSI family can solve your measurement problems. If your measurement needs require low-cost, convenient, and complete test system interfacing, call your local Tektronix Sales Engineer or the Tektronix Sales Representative for your country and ask for a demonstration of the TSI 8150 Test System Interface family. (Tell them you saw it in **HANDSHAKE.**)

To receive a TSI family brochure, use the reply card in this issue of **HANDSHAKE.**

DUT adapter speeds test setup changes

Al Schamel
Instrument Systems Integration Engineering
Tektronix, Inc.

Custom design — specialized solutions, but expensive

System builders often encounter difficulties in providing their own customized physical interface between measurement instruments and the device-under-test (DUT). The costs — mostly in development time, but also in materials and diminished signal integrity — are high.

Customizing an instrument-to-DUT interface starts with one problem and leads to others. Designing an interface for a specific setup is the first step. Designing a flexible interface that can easily be reconfigured for new applications is another problem. Providing service and training — including documentation and replacement parts long after the original system builder has transferred to another job — is yet another problem to contend with.

A complete solution: the TSA 8140 Test System Adapter

The Tektronix Test System Interface family provides a complete switching solution. It also provides a complete, off-the-shelf, physical interfacing solution.

The TSA 8140 Test System Adapter (see Figure 1) is a multipurpose housing which can accept many configurations of switch cards, switch modules, auxiliary mounting units, test head receivers, interchangeable test head adapters, and Virginia Panel Corporation's complete line of vacuum-operated, bed-of-nails, ECB test heads.

Flexibility is the key word for describing the TSA 8140 Test System Adapter. This flexibility starts with mounting for the housing itself (Figures 2 and 3). The housing may be mounted

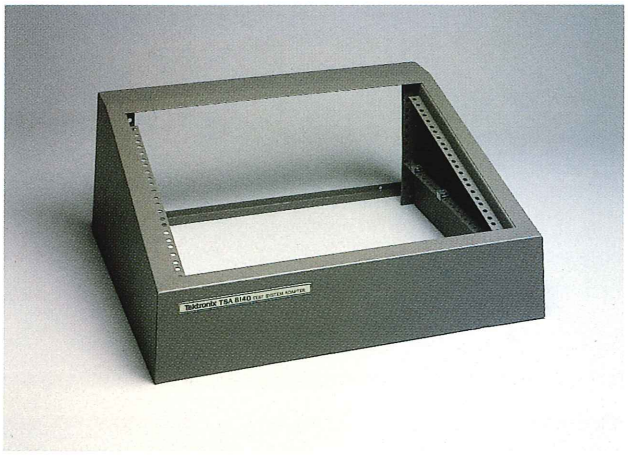


Figure 1. *TSA 8140 Test System Adapter housing.*

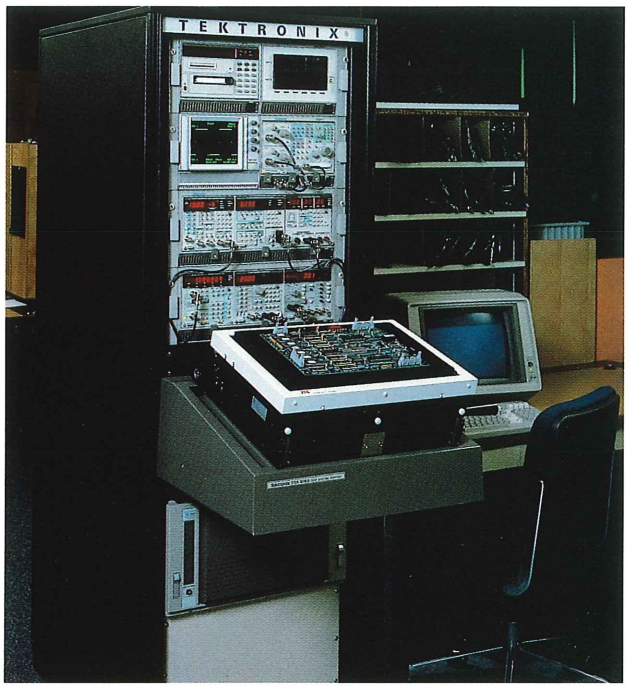


Figure 2. *Horizontal mounting configuration of the TSA 8140 Test System Adapter.*

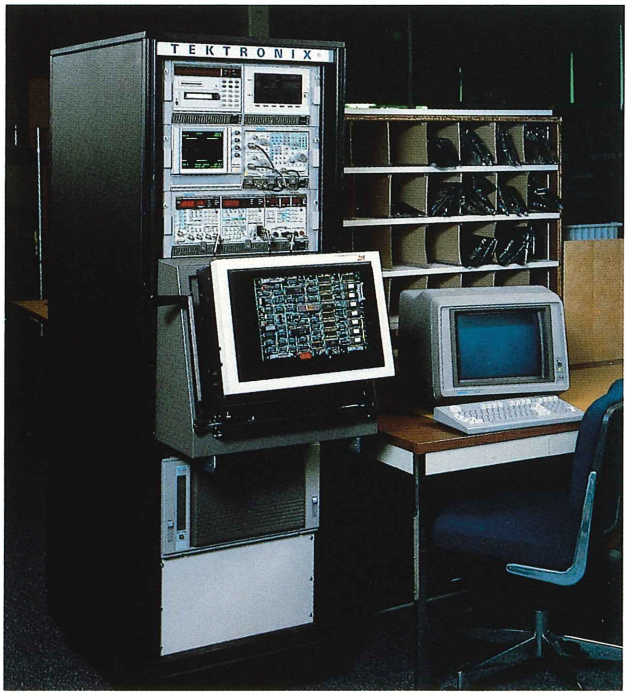


Figure 3. *Vertical mounting configuration of the TSA 8140 Test System Adapter.*

vertically or horizontally, whichever offers the greatest test setup convenience for the user.

In either orientation, auxiliary mounting units (AMUs) may be attached. The 016-0861-00 Auxiliary Card Rack accepts TSI family switch cards for low-frequency applications. The 016-0862-00 Auxiliary HF Mounting Unit accepts switch modules for high-frequency applications. Using AMUs to place switch cards and modules close to the DUT optimizes signal integrity.

TSA 8140 flexibility continues in a patch panel for custom-wired interface circuits. The panel provides the interface between the test head and the system. A breadboard prototype worksurface provides room for custom sockets and connectors.

To extend flexibility in another direction — rapid change of prepared test adapters for a series of DUT tests — the TSA 8140 offers a replaceable top panel. This panel allows the user to easily exchange adapter fixtures.

As a member of the TSI family, the TSA 8140 Test System Adapter is fully compatible with the TSI 8150 Test System Interface mainframe.

Examples illustrate flexibility

Two examples illustrate the flexibility of the TSA 8140 Test System Adapter. The first kind of flexibility is mounting the TSA 8140 itself. The system builder can mount the TSA 8140 in these configurations:

- For desk-top use, such as on a workbench.
- For rack use, in a horizontal configuration.
- For rack use, in a vertical configuration.

The TSA 8140 is also flexible in the choice of test heads the user can insert. The user wires test head connectors to the hinged top panel adapter. For board testing, the user could select a bed-of-nails adapter. For testing components and subassemblies, the user could select a blank test head.

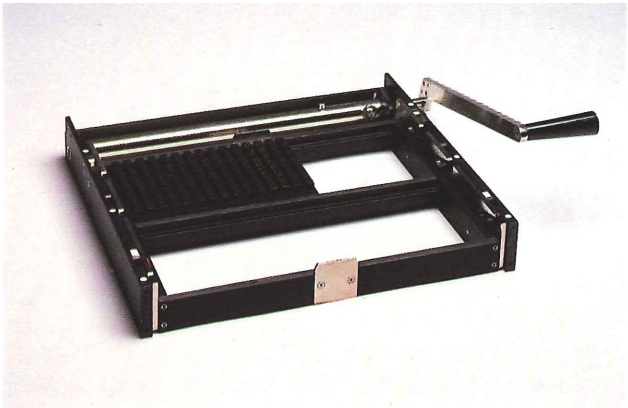


Figure 4. *021-0435-00 TSA 8140 Test Head Receiver.*

Figures 4 through 7 show the optional accessories currently available for the TSA 8140 Test System Adapter: rack mounting kit, test head receiver, interchangeable test head adapter, and Virginia Panel Corporation's line of vacuum operated bed-of-nails fixtures.

Figure 5. *021-0436-00 TSA 8140 Interchangeable Test Head Adapters, single frame.*

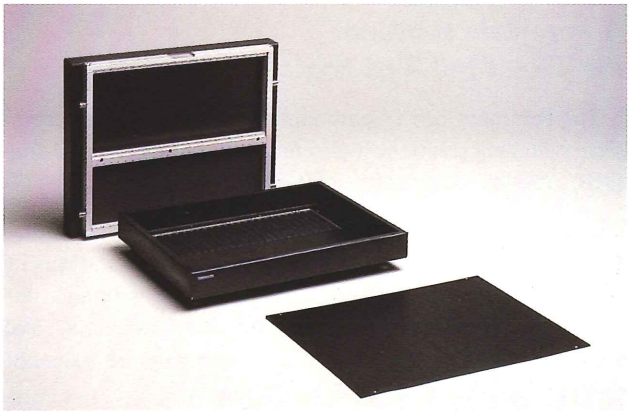


Figure 6. *021-0434-00 TSA 8140 Interchangeable Test Head Adapter, double frame.*

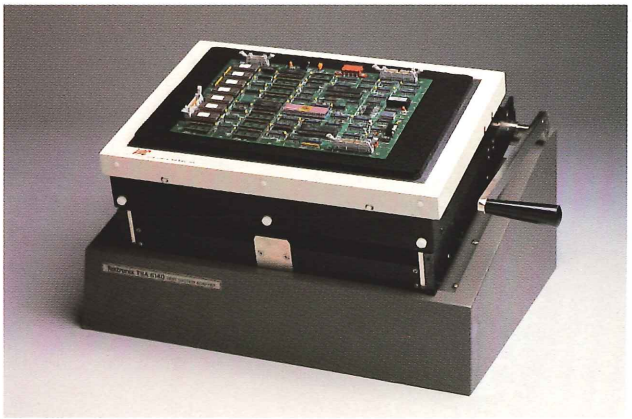


Figure 7. *Virginia Panel Corporation's general-purpose panel, part of a complete line of vacuum-operated bed-of-nails, ECB test heads.*

Conclusion

Together, the removable adapter panels, auxiliary mounting units, and workspaces combine to provide an off-the-shelf, but very flexible, solution to the problem of physically interfacing DUTs in a complex test setup.

For more information on the TSI family, call your local Tektronix Sales Engineer or the Tektronix Sales Representative for your country. To receive a TSI family brochure, use the reply card in this issue of **HANDSHAKE.**

Making automated TDR measurements

John McHugh
Applications Engineer
Instrument Systems Integration Division
Tektronix, Inc.

Sometimes a TDR (Time Domain Reflectometry) measurement can be exactly the measurement technique you need. For example, in production testing; if the impedance of a product you're manufacturing is important — be it printed circuit boards or coaxial cables — you can verify performance with TDR testing. Or when incoming components must pass impedance requirements because an impedance mismatch can cause serious losses in the transmitted signal and result in incorrect data transmissions, you need TDR testing.

In cases like these and many others you can use a Tektronix 7854 Waveform Processing Oscilloscope and a 7S12 Sampler to perform TDR measurements (as well as a variety of more typical sampling measurements). The availability of six sampling heads, two trigger plug-ins, and two pulse generators lets you configure a 7854/7S12 system for a large number of applications. The 7854 has on-board processing capabilities which you can use to make impedance measurements, distance-to-fault calculations, or automatically compensate for errors such as connector discontinuities and skin effect.

Besides versatility, the 7854/7S12 system can perform TDR measurements automatically with the addition of a GPIB instrument controller such as the Tektronix 4041. If many cables or printed circuit board lines (or runs) are to be tested, the TSI 8150 switcher using high-frequency switches (such as the TSS45 or TSS46) can scan the device-under-test quickly and accurately. The instrument controller can tell the switcher which contact to close, execute a 7854 program, read the answer, check against limits, and document the test results to a terminal, line printer, or disk file for later recall.

Connecting a 7854 and the appropriate plug-ins to the device-under-test via the TSI 8150, and the measurement techniques for three common TDR applications are described in the following sections.

Connecting the 7854 to the device-under-test

When connecting a TDR to the device-under-test (referred to as a DUT), connect everything as shown in Figure 1. This routes the pulse from the S-52 pulse generator to the input

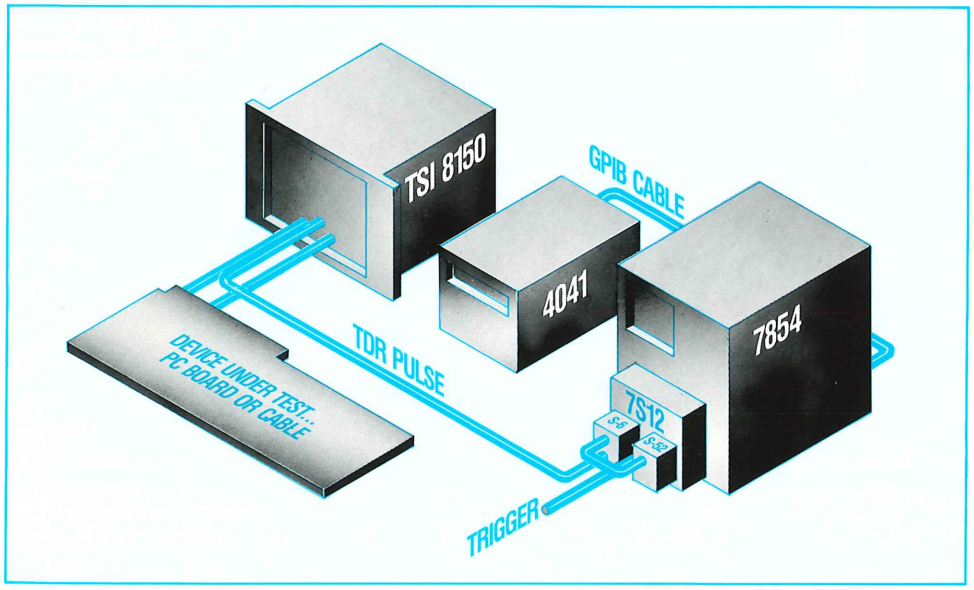


Figure 1. *Test setup for automated TDR measurements.*

What is TDR?

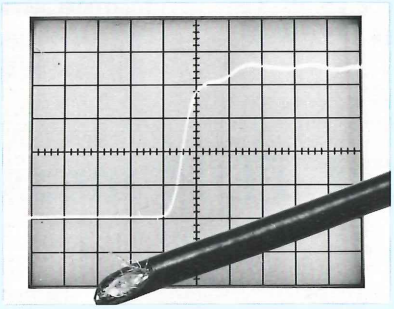
The acronym TDR stands for Time Domain Reflectometry, but it is also often used to refer to a Time Domain Reflectometer, depending on whether you're talking about the measurement technique or an instrument that performs it. The technique is called time domain reflectometry because the x-axis of your measurement is time. (In contrast, the x-axis of a frequency domain measurement is frequency.)

TDR measurements are made by generating a pulse and sending it down any length of cable or printed circuit line. In a defect-free, properly-terminated transmission line, that signal is gone. But if there's any imperfection in the line, part of the signal will be reflected. The shape of the reflection is totally predictable and can be used to characterize the line or identify any discontinuities. A positive-going waveshape indicates an open; a negative-going waveshape is caused by a short. Frays, cuts, crimps, knots, kinks, etc., are shown in a consistent manner. For example, a frayed cable is a positive pulse on the display because it's essentially a "semi-open." Likewise, a crimped cable is a "semi-short" and is shown as a negative spike on the TDR display.

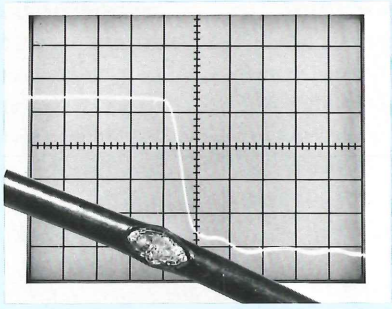
Besides revealing problems, TDR measurements can be used to simply characterize the impedance of a transmission line. But TDR advantages really come to the fore when investigating problems, because TDR displays not only tell you what's wrong, but where it's wrong too. That's possible because you can translate the time (x-axis) into distance if you know the speed of the signal in the line.

Reflection waveshapes

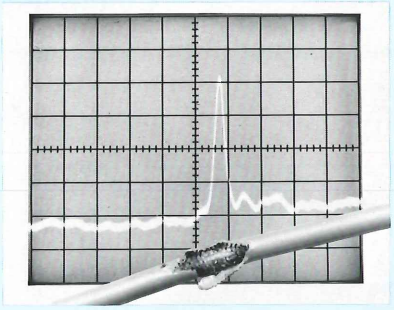
The following waveshapes show typical discontinuities or faults that can be measured using TDR techniques.



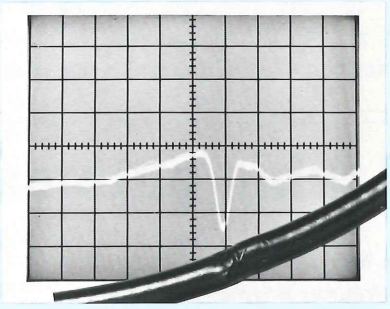
OPEN CABLE: *The waveshape is tipped upward as the impedance increases to infinity.*



SHORTED CABLE: *This is a catastrophic failure. The waveshape turns down as the impedance goes to zero.*



FRAYED CABLE: *This is not a catastrophic failure, but in this example, the impedance is increased by about 8%.*



CRIMPED CABLE: *A crimped cable isn't a catastrophic failure but it leads to a change in the cable's characteristic impedance. As can be seen, the reflected waveshapes of a frayed cable and a crimped cable are distinct, one having a positive-going pulse and the other having a negative-going pulse.*

Skin effect

If a conductor is carrying an alternating current, the current density will be greater at the surface of the conductor than at its center. Induction causes skin effect, which is greater as the frequency increases. Skin effect can, therefore, influence your TDR measurement and should be compensated for as recommended in the accompanying article.

WARNING

Coaxial cables stored on large reels may contain high-voltage capacitive charges resulting from a manufacturer's preshipment tests or a purchaser's acceptance testing. Other transmission lines may be charged with either AC or DC as a result of some line fault. It is important that TDR equipment operators take precautions to ensure that the test line has been safely discharged before it is handled or attached to test equipment.

of the S-6 sampling head for triggering and then on thru the switcher to the DUT. The reflected signal from the DUT returns to the input channel where the signal shape, amplitude, and relative delay provide the information to make the measurements.

The TSI 8150 is shown routing the TDR signal to the DUT. The TSI 8150 can use two different types of switches, depending on the user's needs. The TSS45 switch has a bandwidth of 1.3 Ghz and automatically terminates unused switch contacts to 50 ohms. This switch will cause some reflections to be seen on the 7854 display which can degrade the measurement performance slightly in some cases, but these reflections can also be advantageous because the operator can use them as a reference for other measurements (e.g. distance measurements). The TSS46 is a microwave switcher with a bandwidth of 18 GHz. This switch gives the cleanest TDR measurement because reflections caused by the switcher are minimized. See the other articles in this issue for further details on the TSI 8150 system.

Providing a precision impedance reference

For accurate impedance measurements, a precision reference impedance is needed. If you are measuring impedances around 50 ohms, you should use a 50-ohm precision air line (Tek part number 017-0084-00). If measuring impedances other than 50 ohms (e.g. 75 or 93 ohms), use a reference line as close to the measured impedance as possible (not available from Tektronix) or use appropriate impedance adapters with the 50-ohm precision air line. Adapters available from Tektronix include: 50/75 ohm, 017-0091-00; 50/93 ohm, 017-0092-00; 50/125 ohm, 017-0090-00. For best results, attach the reference line as close to the DUT as possible and then use whatever length of cable you need to get the signal to the measurement system.

Compensating for skin effect

When using a fast pulse in a TDR measurement, the impedance of the cable frequently appears to increase the further down the cable the measurement is taken. This apparent increase in impedance is called skin effect. (See the sidebar "What is TDR?".) There are two ways to compensate for skin effect using the 7854: One is to subtract a reference waveform from the acquired waveform; another is to subtract a calculated skin-effect figure. Because using a reference waveform also removes common errors such as connector discontinuities as well as skin effects from the measurement, a technique using a reference waveform is described below.

TDR measurements using a reference waveform

Subtracting a waveform obtained from a known-good device is an easy way to remove system discontinuities caused by connectors and cabling from your TDR measurement. The program in Figure 2 is an example of this technique.

```
Program:
000  16 AVG STORED
001  0 WFM 3 > WFM
002  STOP
003  16 AVG
004  0 WFM 3 WFM -
005  0 WFM 2 > WFM

Remarks:
000  Average and store the waveform 16 times and display it
001  Store the averaged waveform in location 3
002  Halt program, remove the known-good device, and connect
       the DUT
003  Average this waveform 16 times
004  Subtract the waveform in location 3 from this waveform
005  Store resultant waveform in location 2
```

Figure 2. *Program to subtract a reference waveform.*

Using TDR to characterize cable impedance and determine location of faults

When measuring a cable — be it coax or twisted pair — there are two things you generally look for:

1. The impedance of the cable should stay fairly constant over the entire line.
2. The location of any anomalies, such as dents, nicks, scratches, shorts, etc., in the cable under test.

There are two simple 7854 programs that will allow you to acquire the TDR waveform and automatically measure the cable impedance and distance. These programs are listed as separate entities, but could be incorporated as one program if desired. See Figure 3 for the impedance program and Figure 4 for the distance program.

```
Program:
000  16 AVG
001  STORED
002  CRS2-1
003  STOP
004  1 ENTER VCRD +
005  1 ENTER VCRD - /
006  50 *

Remarks:
000  Average the waveform 16 times
001  Display the stored waveform
002  Turn on the cursors
003  Halt the program to adjust the cursors on the stored
       waveform; cursor 1 to the 50-ohm reference; and cursor
       2 out to the end-point of the measurement
004  First 1 is entered into the X register; VCRD is the vertical
       difference between the cursors in millirho; then the + adds
       1 to this difference; the result is pushed from the X register
       to the Y register by the next instruction
005  Now 1 is entered in the X register again; VCRD - subtracts
       VCRD from 1; lastly, the Y register is divided by the X
       register
006  Multiply the result by the reference impedance (50 ohms)
```

Figure 3. *Program to determine impedance from two points.*

```
Program:
000  16 AVG
001  STORED
002  CRS2-1
003  STOP
004  HCRD
005  3.98 EEX9 *

Remarks:
000  Acquires a signal by averaging it 16 times
001  Displays the stored waveform
002  Turns on the two cursors
003  Halts the program so the operator can put cursor 1 on the
       reference point and cursor 2 to the end of the measurement
004  Enters the horizontal difference between the two cursors in
       the X register
005  Multiplies the contents of the X register (time) by the propaga-
       tion velocity of the medium to get distance in inches
```

Figure 4. *7854 distance measurement program.*

Using TDR to find cable fault locations

A simple algorithm to determine the distance from a point on a waveform to a discontinuity or between any two points on the waveform is:

$$d = 0.5t(C/E)$$

where:

d = distance in inches
t = time from start to end of the measurement
C = 1.18 x 10E10 (speed of light in inches/second)
E = square root of the dielectric constant for the material

NOTE: C/E yields the propagation velocity through the material (V)

This formula can be translated into the following working equation that's executable by the 7854:

$$d = t\ (1/2V)$$

The simple 7854 program shown in Figure 4 implements this equation. It assumes that a poly-type cable (1/2 V = 3.98 x 10E9 for this cable type) is being measured. If another type of cable is being measured, the dielectric constant of the material can be substituted for the poly-type cable constant.

Using TDR to measure printed circuit line impedance

When designing a printed circuit board — especially for high speed logic — consistent impedance is essential. It is not uncommon to have printed circuit lines with impedances of 50 to 60 ohms next to lines of 100 to 150 ohms. After characterizing the circuit board-run impedances, changes in line width and height can be made during the manufacturing process to produce impedances within design specifications.

A TDR measurement can also help characterize the effects of plated-through holes, adjacent lines, spacings, and mounted components on a circuit line's impedance.

The measurement programs used for printed circuit boards are the same as cables. Just think of the lines as tiny cables and use the techniques described for testing cables (see the 7854 programs in figures 3 and 4).

Using TDR to find faults in computer local area networks

Computers have a variety of interconnection cables to allow for communication with other computer systems, shared data bases, etc. Some of the cable systems used are the RS-232-C interface and a wide variety of Local Area Networks (LANs) based on twisted pairs or coaxial cables. The TDR can be used to test these cables and connectors where it would be physically impossible otherwise. Because the 7854 is a digitizer, a "known-good" reference waveform can be saved to disk for recall and compared with a measured waveform at a later date.

Using Tektronix cable testers and TDR techniques with LANs are described in TDR Cable Testers for Installation and Maintenance of Computer Cables, Tektronix literature #22W-5933. Both broadband and baseband systems are covered.

For more information

To get more information on the products or techniques described in this article, contact your local Tektronix Field Office or sales representative. For an application note describing automated TDR testing using the 7854 and 7S12, check the Automated TDR Testing box on the HANDSHAKE reply card included in this issue.

References:

The following Tektronix publications might be useful when using the instruments described here for TDR measurements. For copies, call your local Tektronix Field Office or see the sales representative for your country.

Automated TDR testing made easy with 7854 Oscilloscope/7S12 Sampler Plug-In, 42W-5334-1

7854 Measurement Primer, 42W-5968

7854 Programming Primer, 42W-5926

Preventing Sampling Head Overdrive and Static Damage, 42W-5850

1500 Series TDR Cable Testers, 27AX-3004-4

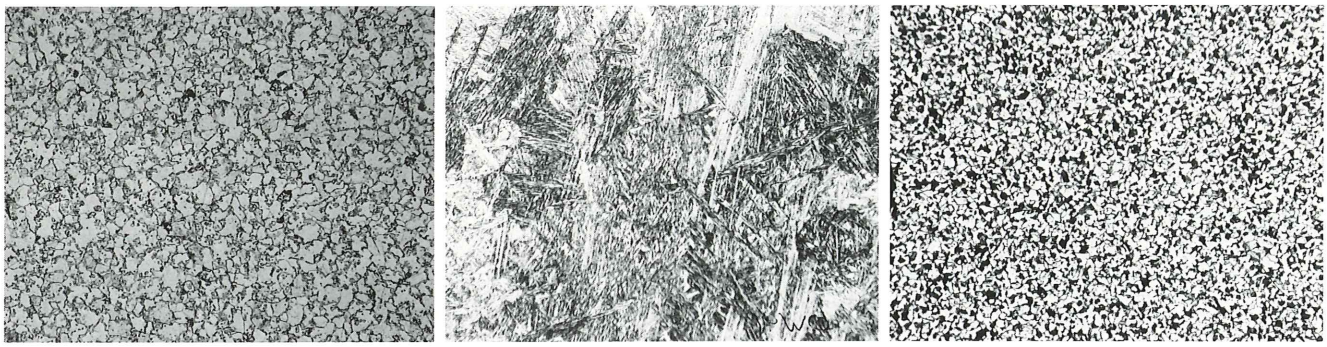
Cable Fault Location, 27AX-4627

TDR for Cable Testers, 27AX-3241-1

TDR Cable Testers for Installation and Maintenance of Computer Cables, 22W-5933-1

Ultrasonic characterization of microstructure

L.P. Scudder
& R.L. Smith
Harwell NDT Centre
Oxfordshire, United Kingdom



Different heat treatments of these chemically identical samples have produced structures whose mechanical properties differ widely as shown by these X100 micrographs. How to monitor these differences quickly and without damage to the sample is described in this article.

Using an ultrasonic system based on a Tektronix WP1310, Drs. Smith and Reynolds developed new ultrasonic attenuation measurement techniques enabling them to make a detailed study of the relationships between the ultrasonic attenuation spectra, microstructure, and fracture properties of engineering materials. Their methods, described in this article by L.P. Scudder and R.L. Smith, revealed that the dislocation damping component of ultrasonic attenuation (scattering and damping) which had been previously ignored at ultrasonic frequencies can, in some cases, be the dominant attenuation factor. Knowledge of this contribution is vital when using ultrasonic techniques of materials characterization.

Background

At the National Non-Destructive Testing (NDT) Centre of the United Kingdom Atomic Energy Authority's (UKAEA) Harwell laboratory, R&D work is carried out to update present NDT methods (such as ultrasonic flaw detection, radiography, etc.) and to develop new and improved methods. One particular interest is the characterization of material structures, especially those of metals, using ultrasonic attenuation measurements.

Ultrasonic attenuation is mainly caused by the inhomogeneous nature of most material structures. Variations in ultrasonic velocity and/or the density through the material cause the acoustic impedance, which is the product of the two, to change. Such "mismatches" of impedance reflect some of the ultrasound wave, thereby attenuating the transmitted beam. In a metal the variations in material structure from grain to grain give rise to impedance mismatches. Depending on the ratio of ultrasonic wavelength (λ) to mean grain diameter ($\overline{D}$), three regions of grain scattering caused by these mismatches can be identified.

For $\lambda/\overline{D} >> 1$, Rayleigh scattering is dominant and the attenuation (α_R) is given by:

$$\alpha_R = C_1 \frac{<D^6>}{<D^3>} F^4 \qquad (1)$$

where:

D = grain diameter
F = ultrasonic frequency
C_1 = constant

For $\lambda/\overline{D} \approx 1$, stochastic scattering dominates and is shown by:

$$\alpha_S = C_2 \overline{D} F^2 \qquad (2)$$

where:

C_2 = constant

Finally for $\lambda/\overline{D} << 1$, diffusion scattering occurs as given by:

$$(3) \qquad \alpha_D = \frac{C_3 F^2}{\overline{D}}$$

where:

C_3 = constant

Apart from grain scattering losses, we have found that a second comparable loss occurs for metals. This correlates with losses from the damping of dislocation vibrations which are driven by the ultrasound. A simple model predicts this loss to be:

$$(4) \qquad \alpha_d = C_4 F^2$$

The total attenuation is the sum of (4) and, depending on the frequency range, (1), (2), or (3). The experimental data can be interpreted using this model by plotting it in the form $\alpha(F)/F^2$ v F^2. This separates the grain scattering and dislocation contributions. For instance in the Rayleigh region:

$$(5) \qquad \alpha(F) = C_1 \frac{<D^6>}{<D^3>} F^4 + C_4 F^2$$

$$(6) \qquad \frac{\alpha(F)}{F^2} = C_1 \frac{<D^6>}{<D^3>} F^2 + C_4$$

The gradient of the graph, gives a measure of the grain volume $<D^6>/<D^3>$ (tends to $\overline{D}^3$ for narrow grain size distributions) and the intercept (C_4 is the dislocation damping constant) tells us about the dislocation population of the metal. Figure 1 shows the information that can be obtained from this analysis over the three frequency regions.

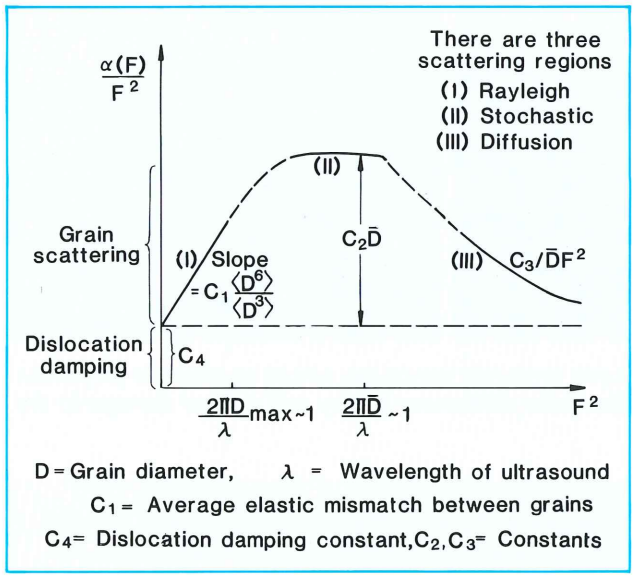


Figure 1. *Analysis of attenuation data.*

Equipment

To make accurate attenuation measurements the equipment shown in Figure 2 is used. A broad band ultrasonic transducer, whose fundamental resonance is 50 MHz, gener-

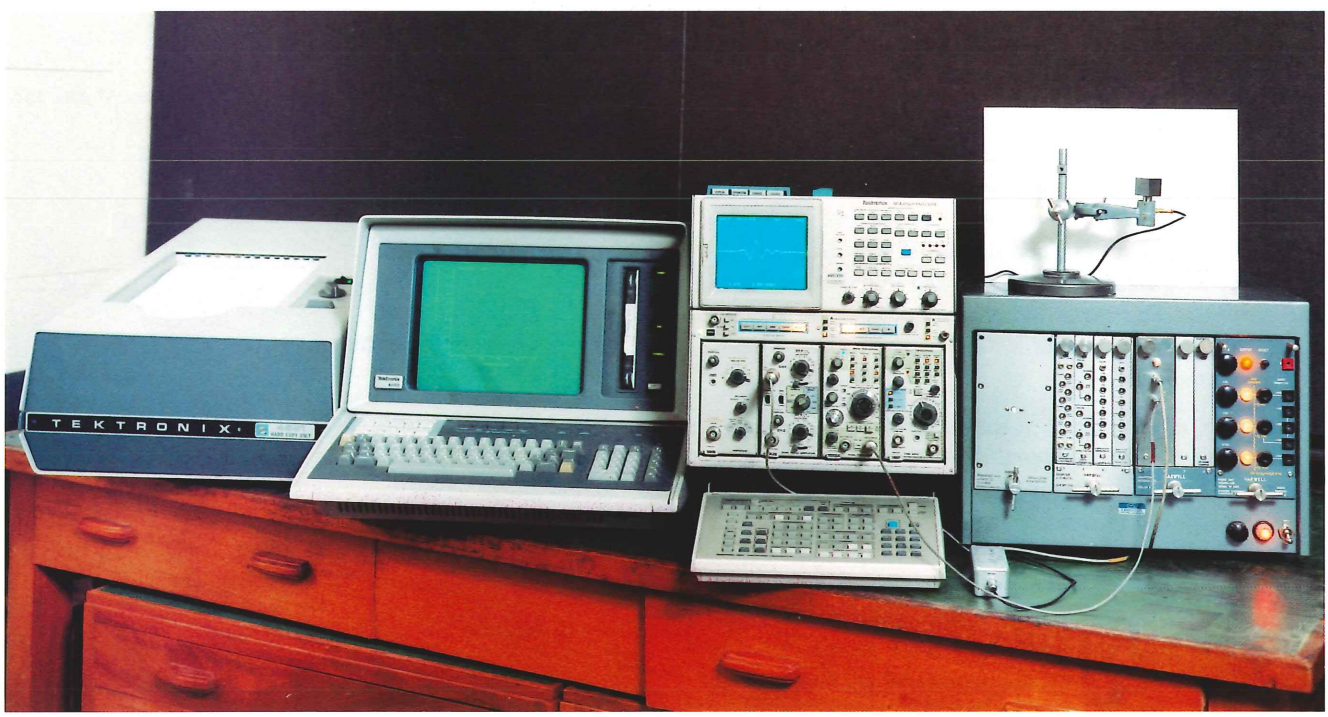


Figure 2. *Test equipment setup.*

ates and receives ultrasound. Bonded to the front of its element is a quartz delay line which enables the echo from the interface between it and the specimen to be collected. This echo is used in the analysis to eliminate inherent transducer characteristics from the data.

The transducer is driven by a custom built pulser-receiver unit which also receives the reflected signals. Output from the receiver is fed to the Tektronix WP1310 Signal Processing System (7854 Waveform Processing Oscilloscope, 4052 Computer, 4631 Hard Copy Unit, all linked via the GPIB).

Operation

Figure 3 shows a flow diagram of the program. To record the signals, use is made of the 7854's digital averaging facility. The digitizing process is controlled by a program running on the 4052 which sends commands to the 7854 through the GPIB. The first task when starting this program is to enter the parameters of the transducer (element diameter, delay line length, delay line velocity) and the sample under test (sample thickness, velocity of sound in sample). These parameters are used in analysis of the echoes.

Often the velocity of sound in the sample is unknown and must be measured and entered into the program before recording the echoes to be analyzed. The program asks if such a measurement is required. If so, it instructs the user to display two consecutive echoes from the back wall of the sample on the 7854, using the delay-time mode of a Tektronix 7B92A time base. These are digitized by a user-initiated command from the 4052 to the 7854. On completion of digitization, the user positions one of the 7854's measurement cursors on a peak in the first echo and the other cursor on the corresponding point in the second echo. The time delay between the cursors, and hence the echoes, is then transferred to the 4052 which uses this and the entered sample thickness to calculate velocity. A facility is also provided to enable repeated measurements of the time delay to obtain an average velocity. This enables velocity measurements to be made to an accuracy of 0.1%.

The next stage in the program controls the digitization of the echoes to be processed for their attenuation data. These echoes are the echo from the transducer/sample interface (echo A) and two consecutive echoes from the specimens back surface (echoes B and C respectively). Each echo is brought individually onto the screen and, on command from the user, is digitized by the 7854 for the number of averaging cycles recorded in the program. When complete, the digitized echo is transferred to the 4052 and stored in an array. The same procedure is carried out for each of the echoes until all three are stored in the 4052. The program now instructs the 4052 in processing the echoes to obtain the attenuation data.

The first stage in processing involves generating the frequency spectrum of each pulse by using the fast Fourier transform facility of the 4052 signal processing ROM (R08 Signal Processing ROM Pack). Each spectrum is stored in the form of cartesian complex numbers in the array used for its original time domain waveform. Since we are interested in

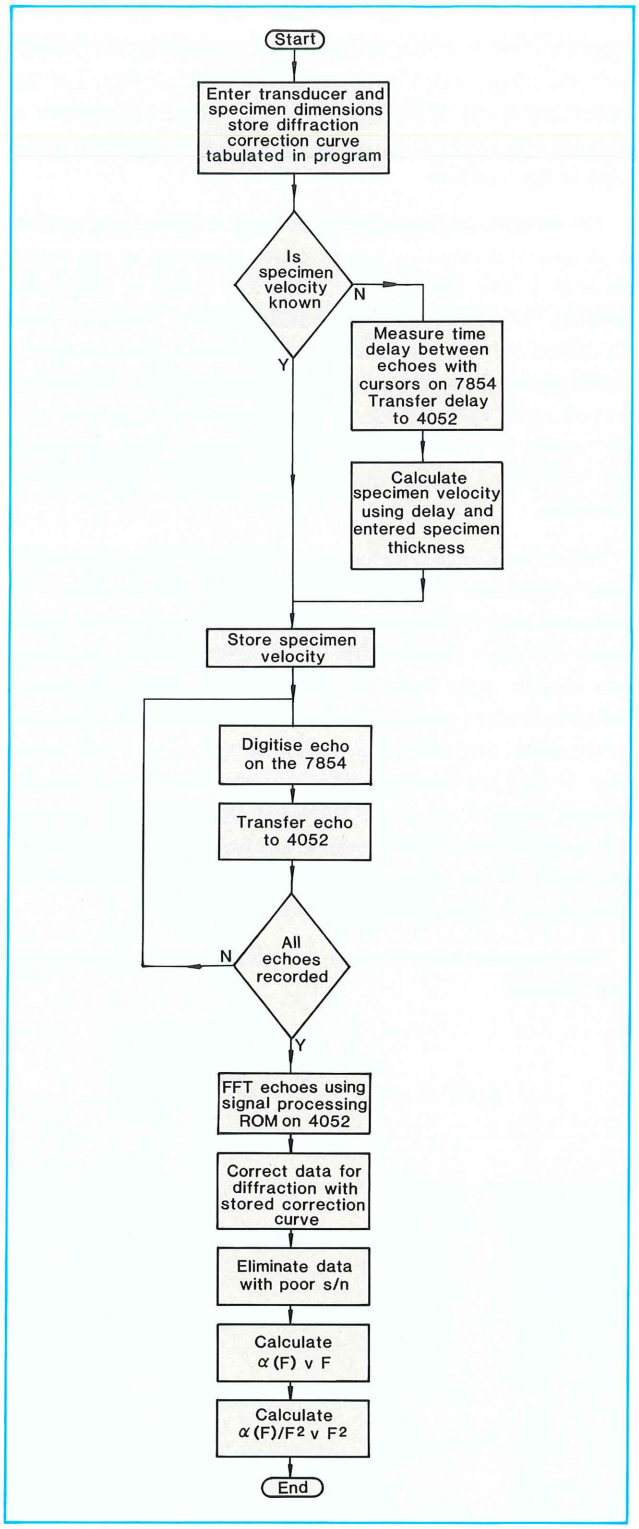


Figure 3. *Simplified flow chart of the program.*

measuring the amplitude of these spectra, the Cartesian representation is converted to a polar representation (amplitude and phase angle) by use of the POLAR command of the signal processing ROM. Only the amplitude information is retained and stored in the array since phase information is not used in the analysis.

The ultrasound, being produced from a finite-sized source, is subject to diffraction which causes spreading of the beam. So even in the absence of attenuation, a loss in amplitude between the echoes, and hence their spectra, would be seen. To correct for this a normalized diffraction correction curve, stored in tabular form within the program, is used. This curve was obtained by modeling the diffraction from a circular piston source of sound. Points falling between those tabulated are calculated using three-point Lagrange interpolation formulae.

Once the spectra have been corrected for diffraction, some data is discarded because of its poor signal-to-noise ratio. The criterion used ignores data at frequencies which have amplitudes less than 17-dB below the maximum in the spectra of the weakest echo (echo C). To locate the 17-dB level, the maximum of the spectrum is found using the MAX command of the signal processing ROM and the level is set 17-dB below this. To find the corresponding frequencies for which the amplitude is below the 17-dB level, the crossing points between the level and spectrum of echo C are found using the CROSS command of the signal processing ROM. Data at these frequencies are then removed from the data table.

The program is now ready to calculate attenuation using the formula:

$$\alpha(F) = \frac{n\left(-\dfrac{R(F)}{B(F)\,C(F)}\right)}{2L}$$

where:

L = sample thickness

R(F) = reflection coefficient of the transducer/sample interface which is given by:

$$R(F) = \left(\frac{A(F)\,C(F)}{A(F)\,C(F) - B^2(F)}\right)^{\frac{1}{2}}$$

where:

A(F), B(F), C(F) = diffraction-corrected frequency spectra of the three echoes.

The attenuation data is then output in tabular and graphical form. From the raw attenuation data the $\alpha(F)/F^2$ v F^2 data are also calculated and output in the same forms. Hardcopy of the output is provided by a Tektronix 4631 copier linked to the 4052. To produce a full set of attenuation data takes about five minutes. This is very rapid compared to the analogue spectrum analysis technique that was previously used. However, this could be reduced even further through program refinements. Typical attenuation values are produced over a bandwidth of 17 MHz to above 40 MHz with an estimated accuracy of 10%.

The $\alpha(F)/F^2$ v F^2 data we have obtained from metals using these techniques correlate well with the model outlined in equations 1 through 6 and Figure 1. For instance, Figure 4 shows the $\alpha(F)/F^2$ v F^2 data from two pressure-vessel steels which have approximately the same dislocation content but different grain sizes. It was predicted earlier that in the Rayleigh scattering region this would give $\alpha(F)/F^2$ v F^2 plots with approximately the same intercept but different gradients. This is clearly shown by the data.

The second example shown in Figure 5 is for an aluminum sample in which the grain size has been kept constant but the dislocation content has been varied by straining the sample. Again a prediction for the behavior of the $\alpha(F)/F^2$ v F^2 data

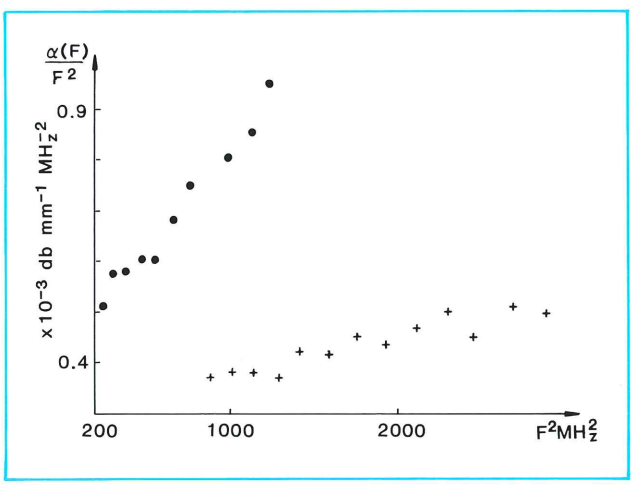


Figure 4. *Ultrasonic attenuation in pressure-vessel steels.*

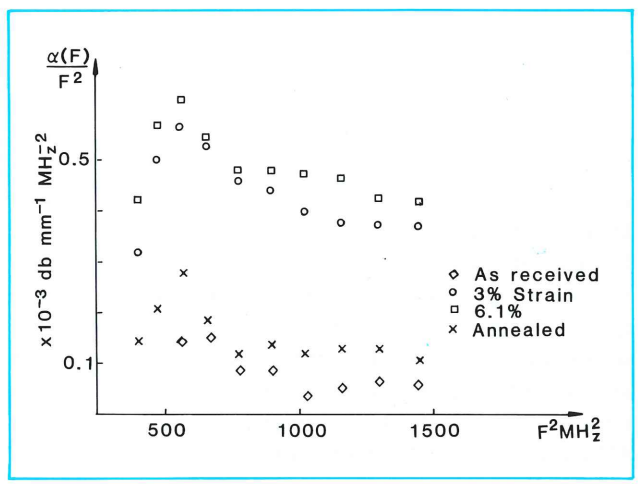


Figure 5. *Ultrasonic attenuation in aluminum.*

is that the grain scattering across all frequency regions will remain constant but the dislocation base level will vary. The data shows this quite clearly since the shape, which is produced by grain scattering, is constant but the level varies in line with the strain.

Summary

At present the system and analysis has been used to gather information on microstructural changes in metal products (steel, aluminum, copper, nickel, titanium, and cast iron) for which control of the microstructure to optimize mechanical properties is important. From such information we envisage the design and construction of dedicated instruments for the rapid on-line monitoring of microstructural quality.

Acknowledgments

These techniques and the application of the WP1310 have been developed over a number of years. The authors would like to acknowledge the contributions made by W.N. Reynolds, B. Hudson, S. Perring, R.B. Brightwell, K.L. Rusbridge, H.N.G. Wadley, and J. Greaves.

About the Authors

Dr. Ronald L. Smith has a BSc in Physics and PhD in Magnetism, both from the University of Durham. He works in the National NDT Centre, AERE, Harwell, England and is responsible for the development of NDT techniques for defect detection and materials characterization. Enquiries on this work should be made on (0235) 24141 Ext. 2512.

Lawrence P. Scudder graduated with a First Class Honours Degree in Physics from the University of Sussex in 1983 and since then has been primarily involved in the development of ultrasonic techniques for the characterization of engineering materials.

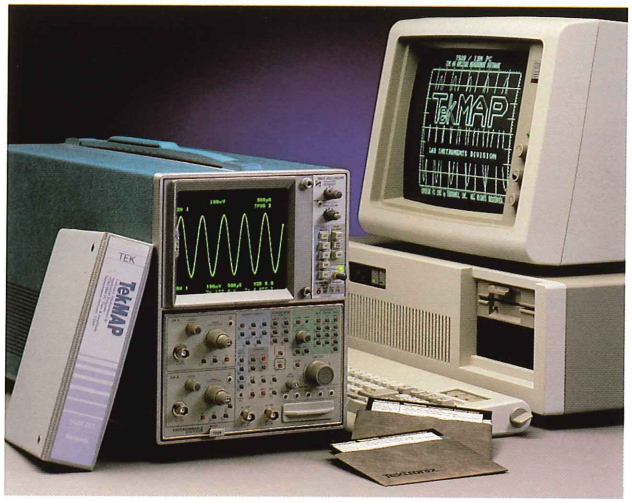
References

Perring, S., R.L. Smith, W.N. Reynolds, and B. Hudson. The role of dislocations in ultrasonic attenuation. AERE R11384 to be published in PhiliMag.

Reynolds, W.N. and R.L. Smith. Ultrasonic wave attenuation spectra in steels. J. Phys. D. App. Phys. 17, (1984), 109-116.

Smith, R.L., K.L. Rusbridge, W.N. Reynolds, and B. Hudson. Ultrasonic attenuation, microstructure, and ductile to brittle transition temperature in Fe-C alloys. Mat. Eval. 41, (1983), 219-222.

TekMAP for the 7D20: IBM PC and HP 200 Series



Two new software products supporting the Tektronix 7D20 Programmable Digitizer are now available.

7D20/IBM PC Time and Amplitude Measurement Software

This package supports basic waveform processing and pulse parameter measurements on data acquired with a 7D20 and analyzed on an IBM PC. As a low-cost, general-purpose design and evaluation engineering package, this TekMAP software provides for waveform acquisition (including autoranging), archival storage and retrieval of waveforms and settings data, as well as hard copy output.

Processing speed has been enhanced by taking advantage of the 8087 (80287) co-processor chip, and by using the C programming language to generate compiled code.

The easy-to-use interface is similar to the initial-command-letter/cursor-movement interface familiar to users of Lotus 1-2-3 and other popular software packages.

7D20/HP Series 200 Time and Amplitude Measurement Software

This time and amplitude measurement package extends the versatility of the Tektronix 7D20 Programmable Digitizer by integrating the 7D20 with the Hewlett Packard Series 200 Technical Computers.

The 7D20 may be operated entirely from the computer or from its own front panel. Measurement routines available include these pulse parameters: maximum amplitude, minimum amplitude, mid-amplitude, peak-to-peak amplitude, 0% and 100% levels, RMS voltage, risetime, falltime, width, period, frequency, % overshoot and undershoot. A propagation delay routine measures time delay between cursors positioned on either one or two waveforms. Fast Fourier transforms can be performed with an optimized power-of-four algorithm.

For more information

If you want to find out more about these Tektronix products, please contact your local Tektronix Field Office or sales representative for product, price, and availability information. For data sheets describing these products, you can use the **HANDSHAKE** reply card included in this issue.

All this and programmable too!

What do you do when you're trying to track down an elusive transient in a circuit design? You could assemble a lot of bulky, expensive test equipment. Or you could redesign the circuit in an attempt to eliminate the problem. But now there's a better answer! Now you can turn to the newest member of the Tektronix 2400-Series portable oscilloscope family for help — the 2467 Oscilloscope.

The 2467 brings new capabilities to portable measurements. One major feature is a high visual writing rate which allows the display of one-nanosecond pulse transitions, even under normal lighting conditions. This is all made possible through the use of a microchannel plate (MCP) CRT which provides a visible display of low repetition rate transients superimposed on high repetition rate signals through a feature called adaptive intensity (see sidebar "What is a microchannel plate" for details).

Another important feature is the auto setup mode. Pressing a single button automatically scales all selected vertical channels for amplitude and position, sets the time base for two to five signal periods — or for the pulse width, if the pulse is narrow — and adjusts the trigger for a stable display. All of this in about one second to provide an instant display and a convenient starting point for further measurement.

Since the 2467 is a portable oscilloscope, it can easily be taken to the measurement. And it meets all the tests of being portable: Light weight, rugged construction, and adaptability to severe environments.

With a GPIB interface provided by Option 10, the 2467 becomes an ideal component of a semiautomatic test and measurement system. A host controller can control front-panel settings and display operator prompting messages on the 2467 CRT. The controller can also read front-panel settings and the results of voltage, time, frequency, phase, and ratio measurements over the bus.

Packed with features

The 2467 has many standard features which both save time and make measurements quick and convenient. These include:

Auto setup automatically scales vertical, horizontal, and trigger systems to quickly display all selected channels.

Sequencing between steps in specified order at the touch of a button.

Save/Recall stores 20 complete instrument setups in nonvolatile memory for later recall.

Voltage and time cursors with on-screen readout let you measure voltage differences and time intervals with ease and accuracy for direct measurement of frequency, voltage ratio, duty factor, and phase difference.

Cursors after delay let you use the delayed sweep to magnify signal details of interest, then accurately measure them with the voltage or time cursors.

On-screen scale factor readout displays all instrument control settings and measurement results. Besides measurement convenience, this provides complete documentation on waveform photographs.

Trigger initialization at 50% provides single-button setup of trigger level midway between high and low signal peaks.

On-screen trigger level readout eliminates time-consuming trial-and-error triggering.

A family resemblance

Any operator currently using a 2400 Series oscilloscope already knows how to operate the 2467 — all of the operating features are the same. In addition, the 2467 shares many of the options that have made earlier members of the 2400 Series family popular measurement instruments. In summary, these options are:

Option 05 — TV waveform measurement system.
Option 06 — Counter/timer/trigger.
Option 09 — Counter/timer/trigger with word recognizer.
Option 10 — GPIB interface.
Option 1R — Rack mounting.

For more information

If you want to find out more about the 2467, please contact your local Tektronix Field Office or sales representative for your country. For a data sheet describing the 2467, use the **HANDSHAKE** reply card included in this issue.

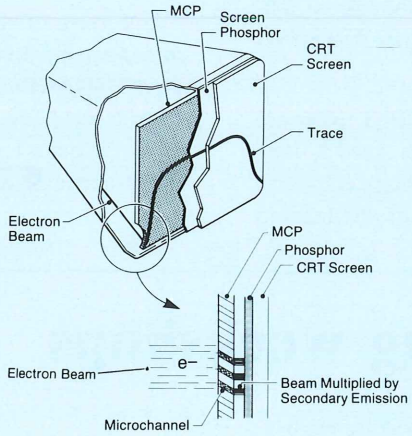
The 2467 is also available through the Tektronix National Marketing Center. Call 1-800-426-2200 toll-free (in Oregon call 627-9000 collect) and tell them you saw it in **HANDSHAKE.**

What is a microchannel plate?

An oscilloscope CRT based on microchannel plate technology is quite similar to a conventional CRT. The major difference is the microchannel plate (MCP) located just behind the CRT phosphor screen. The accompanying picture shows details of an MCP CRT.

The MCP uses a 0.050-inch glass plate with multiple closely spaced holes located directly behind the standard phosphor screen. 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.

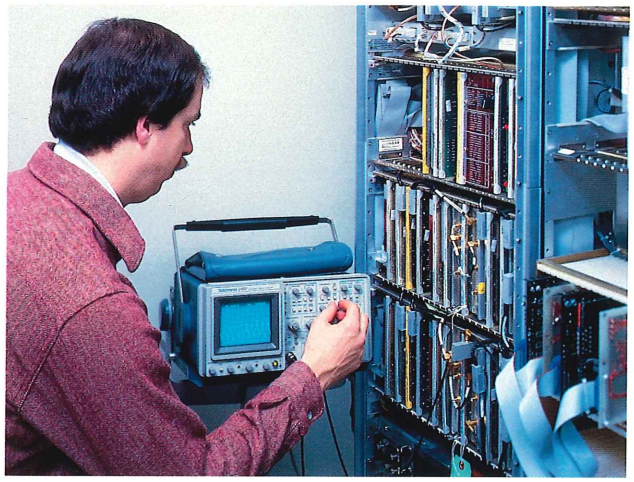
When the electron beam scans across the MCP, electrons enter the holes and strike the treated sides. This causes secondary emission within the channel which is amplified by further secondary emission as it moves down the channel. The amplified electron beam exits the channel and travels the short distance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



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.

Portable scope bares hidden signals



Floating responses like aberrant signals, unseen jitter, the one-in-a-thousand switching fault, and the random glitch have often eluded design troubleshooters. Conventional scopes usually cannot reveal signals that occur too infrequently to sustain display-phosphor excitation. The newer digital storage oscilloscopes (DSOs) increase the likelihood of getting a clearer display by using special enveloping or glitch-capture modes. Even then, however, a capture may consist of only a few samples of the troublemaker. As a result, the usual quick probing of test modes in search of circuit faults turns up nothing. Meanwhile, within the circuit, a malfunction such as a metastable flip-flop might cause a problem every 10,000 or so clock cycles on 10% of the devices.

With this introduction to the article "Portable analog scope bares signals hidden even from digital storage units." **Electronic Design,** March 20, 1986, Rod Bristol and Alfred K. Hillman set the stage for describing the capabilities of the new Tektronix 2467 Oscilloscope. Included in the article are a description of the microchannel-plate CRT and a typical measurement problem which can best be solved with the 2467.

For a reprint of this article, check the appropriate box on the reply card in this issue of **HANDSHAKE.**

Data extraction from noisy signals

A reprint available from Tektronix describes some measurement techniques that can help you find what you need even in very noisy signals — when the signal to noise ratio is 1.0, or even 0.1! The trick is a DFT (discrete Fourier transform) running on a PC.

The article, "Use a personal computer and DFT to extract data from noisy signals" first appeared in the April 5, 1984 issue of EDN. It describes the technique in detail, compares the DFT with the FFT, describes the effects of aliasing and windowing, and illustrates how to produce an accurate computer model.

If a copy of this literature will help you solve test and measurement problems, check the appropriate item on the HANDSHAKE reply card included in this issue. Often a call to your local Tektronix Field Office — or the sales representative for your country — will get you the information you need sooner.

Customer training workshops

For the convenience of Tektronix customers with application or operational training needs, here is the schedule for workshops to be offered in mid-1986 by Tektronix IG Customer Training.

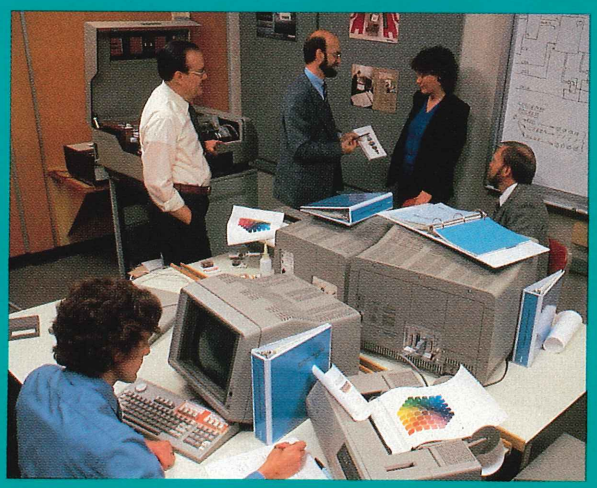
CLASS	LOCATION	DATES
Digital Storage Oscilloscope Workshops		
Basic Digital Fundamentals (using the 2230 Oscilloscope) and Advanced Digital Measurements (using the 2430 Oscilloscope)	Irvine	Sept 9-11
	Boston	Sept 23-25
	Salt Lake City	Oct 7-8 (2430 only)
	Denver	Oct 14-16
	Cincinnati	Oct 29-30 (2430 only)
	Philadelphia	Nov 18-20
	Cleveland	Dec 3-4 (2430 only)
Waveform Processing (using the 7854 Oscilloscope)	Washington DC	Sept 10-11
	Denver	Sept 24-25
	Detroit	Oct 8-9
	Santa Clara	Oct 21-22
	Huntsville	Nov 5-6
	Boston	Nov 19-20
	Cleveland	Dec 3-4
Advanced Waveform Processing (using TEK SPS BASIC, 7612D Digitizer, 7912AD Digitizer)	Woodbridge	Sept 30-Oct 3
	Santa Clara	Oct 28-31
Analog Realtime Oscilloscope Workshops		
XYZ's of Using a Scope (based on the 2200 Series)	Philadelphia	Sept 23
	Boston	Oct 28
Parametric Measurements and Advanced Parametric Measurements (using the 2445/2465 Oscilloscope)	Dallas	Oct 8-9
	Boston	Oct 29-30
	Chicago	Nov 12-13
Controllers and Other Workshops		
Using Sampling Techniques	Salt Lake City	Oct 2
	Santa Clara	Oct 23
	Huntsville	Nov 7
	Boston	Nov 21
Using a 4041 Controller for Automation	Santa Clara	Sep 3-5
	Chicago	Sep 16-18
	Ft. Lauderdale	Nov 11-13

Workshop sizes are limited. We recommend that you enroll early.

For more information or to register for these workshops, call Tektronix IG Customer Training, (503)642-8013, or contact your local Tektronix Field Office.

We retain the option to cancel or reschedule a workshop.

The People Behind the Product are Friendly and Ready to Help You



Training is an investment for your company. Tektronix workshops develop your people and are one of the best methods of deriving more effective utilization from your equipment.

Training gives you a new perspective on your applications. Professional instructors are available to help you solve your application problems during laboratory sessions.

Training provides you with new methods of making measurements. Our workshops are designed to aid in developing new ideas through comprehensive discussion and laboratory exercises.

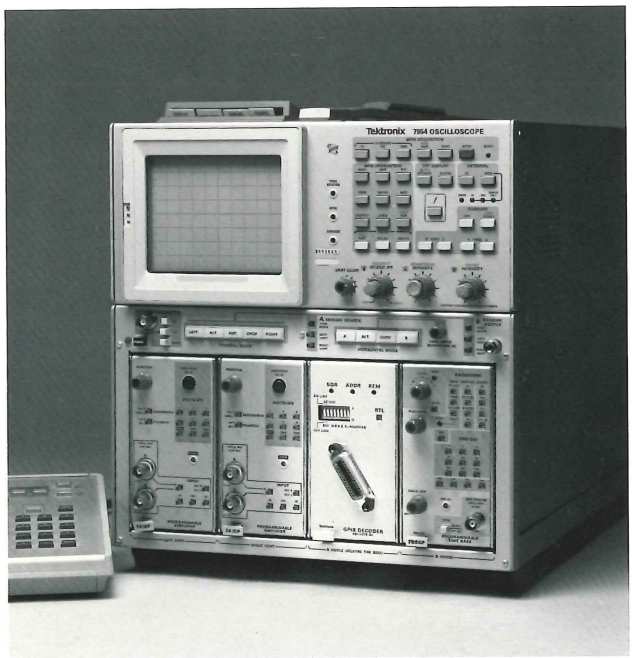
For your convenience, Tektronix also offers private workshops that can be conducted at your company. Call us for more information.

If you are interested in registering for one of these workshops or would like more information, call Instrument Group Customer Training at (503) 642-8013 or 1-800-225-7802.

For a schedule of upcoming workshops, please refer to the **Customer training workshops** article in this issue of HANDSHAKE.

Tektronix®
COMMITTED TO EXCELLENCE

GPIB Decoder adds programmability to 7854



The Tektronix 7854 Waveform Processing Oscilloscope has many fans in the systems world — and more than a few of you have wished to program the vertical amplifier and time-base settings of the 7854. Now you can.

The device that lets you do it is the GPIB Decoder. It fits into one of the time-base slots of the 7854 and allows you to operate two 7A16P Programmable Amplifier plug-ins and a 7B90P Programmable Time Base in the three remaining 7854 slots.

Both the 7A16P and 7B90P are fully programmable plug-ins. Complete instrument set-ups can be sent from a computer over the GPIB and routed through the GPIB decoder to each plug-in. Or, first-time set-ups can be done manually at the plug-ins and the settings read over the GPIB by the computer for future use in an automated measurement set-up.

In addition to being fully programmable, the 7A16P Programmable Amplifier provides calibrated deflection factors from 10 mV/div to 5 V/div, a 200-MHz bandwidth, and selectable input impedances of 50 ohms and 1 megohm.

The 7B90P Programmable Time Base has calibrated sweep rates from 500 ps/div to 500 ms/div, and a 400-MHz trigger bandwidth. It can also be operated in either repetitive or single-sweep modes.

These programmable plug-ins and the GPIB Decoder slide into the 7854 as a unit in a factory-cabled configuration. For GPIB Decoder/plug-in configuration and price information, contact ISI Marketing, P.O. Box 1700, Beaverton, OR 97075, U.S.A., or call 206-253-5655.

HANDSHAKE
Group 157 (54-016)
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

BULK RATE
U.S. POSTAGE
PAID
Tektronix, Inc.

58-204
ROBERT A MALINEN
HANDSHAKE

We Need Your Help!
We need your help in keeping our mail list current and up-to-date. Take a few moments to look at the label on this issue. If the address is incorrect in any way or the addressee is no longer with your company, please send us a correction using the reply card in this issue. Thanks for your help!

Address Correction Requested—Forwarding and Return Postage Guaranteed.

49W-6331