TEK APPLICATION INFORMATION

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HANDSHAKE

NEWSLETTER OF SIGNAL PROCESSING AND INSTRUMENT CONTROL

- NEW PROFESSIONAL AUDIO TEST PACKAGE
- ULTRASONIC TESTING AT BOEING
- SYSTEM SOFTWARE LIBRARY

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In this issue

This issue of **HANDSHAKE** features two new exciting product introductions from the Tektronix Instrument Systems Integration Division. The first is the MP 2902, a Measurement Package of hardware and software designed to automate audio testing. The MP 2902 includes a menu driven automatic test program generator (ATPG) so easy to use that even non-programmers can generate fast, productive programs. These programs can be either in the MP 2902 ATPG format or in 4041 BASIC.

Speaking of the 4041, there's news about it in this issue also. There's been a significant upgrade of the Tektronix 4041 System Controller. More power and lower price are two consequences of the changes. And the 4041 now has a disc drive option featuring both floppy and hard drives.

Tektronix systems users at Boeing Aerospace Company contributed **"Digital pulse-echo techniques for advanced composites". HANDSHAKE** is proud to publish this article by John L. Cline and R.L. Carlsen because it's an interesting, comprehensive, and well-written description of pulse-echo ultrasonics in non-destructive evaluation.

In this issue, we've also included a **HANDSHAKE** index: a by-subject listing of the contents in the last two years of **HANDSHAKE**. If you see something you missed, write us here for back issues:

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Audio analyzer system creates automatic test programs — without programming

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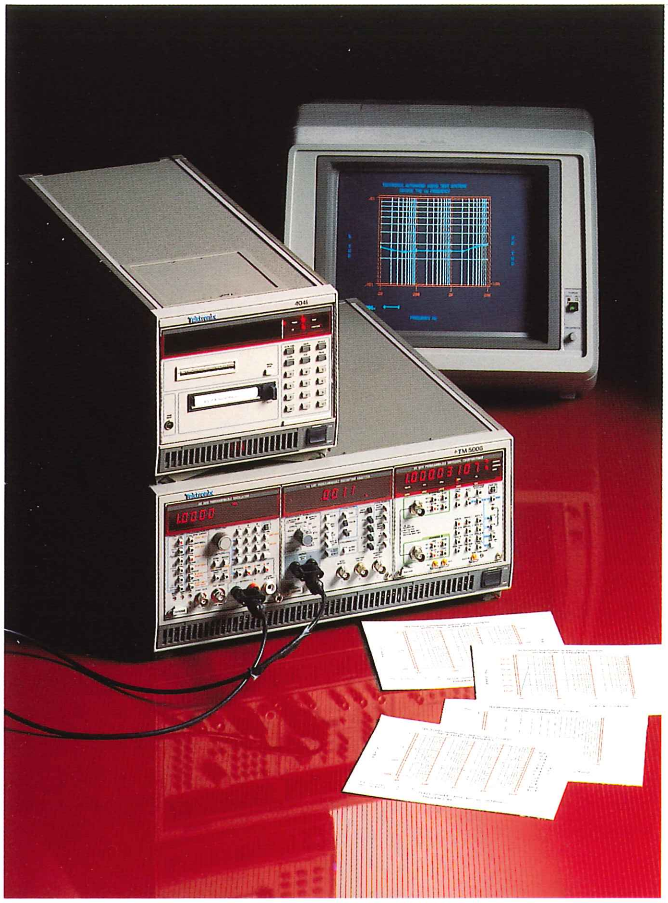


The Tektronix MP 2902 Audio Measurements Package offers the hardware and software needed to create and run a variety of tests quickly and easily. This tightly integrated hardware/software package automatically — and inexpensively — documents test results in graphic or tabular form.

Repetitive audio tests need to be thorough and accurate, which means they can be just as tedious, slow, and error-prone as they are essential. For many applications, automation is the answer. It speeds tests, simplifies procedures, minimizes operator errors, and provides documented results.

One approach to automating is building your own system. That means first you buy the hardware. Then you buy the software you need to write a program that controls the hardware, makes the measurements, processes and stores the data. If you have little or no programming skill, this can be an intimidating step. Even if you have strong programming skills, you may dread this necessity.

The other approach to automated audio testing is the Tektronix MP 2902 Audio Measurements Package. It's called a "package" for a good reason: it is a tightly integrated set of audio measurement hardware and software.

The MP 2902 hardware consists of a signal source, an audio analyzer, and a system controller with keyboard and screen — all designed to work together. The source provides a stimulus for the device-under-test (DUT). The analyzer measures the DUT output. The controller handles the data and sets up the analyzer and source. The system talks to you through the screen, and you talk to the system through the keyboard.

The MP 2902 software is essentially two parts: an Automatic Test Program Generator, and 4041 BASIC — an enhanced BASIC optimized for systems applications.

This package saves time in three ways. You save installation time because it's a complete and versatile package and you don't waste time evaluating individual pieces. Second, because the MP 2902 has a menu-driven Automatic Test Program Generator, it's quicker and easier to write automatic test procedures. Third, automated testing is fast. An automated frequency response test — with 30 frequency points specified — is three to five times faster than performing the same tests manually.

Nearby are boxed descriptions of the MP 2902 hardware (with specifications) and of some typical measurement package applications. But the real power of this package is best illustrated with the MP 2902 software.

MP 2902 software

MP 2902 software gives you the best of two worlds:

- The Audio Test Program Generator (ATPG), in an easy, straight-forward manner, lets you create test procedures.
- 4041 BASIC flexibility helps you customize the automated test procedure for special measurement or data presentation needs.

You select from a series of menus and the ATPG builds a test procedure database. (The database is a set of test steps, as Figure 1 shows.) Next, you translate the procedure database into a BASIC language program. This translation process is easy ... it involves answering only a few set-up questions. Let's see how it works.

An ATPG application

These steps illustrate building an automated test procedure. Assume you have a manual test procedure established and you have:

- Installed the MP 2902 instruments.
- Connected the SG 5010 OUTPUT to the device-under-test (DUT) input and the DUT output to the AA 5001 INPUT.
- Loaded the system software into the 4041 System Controller.

Building test procedures consists mostly of reading menus and pressing keys. Figure 2 shows the menus and the usual paths between them. Figure 3 shows the function keys at the top of the 4105 keyboard.

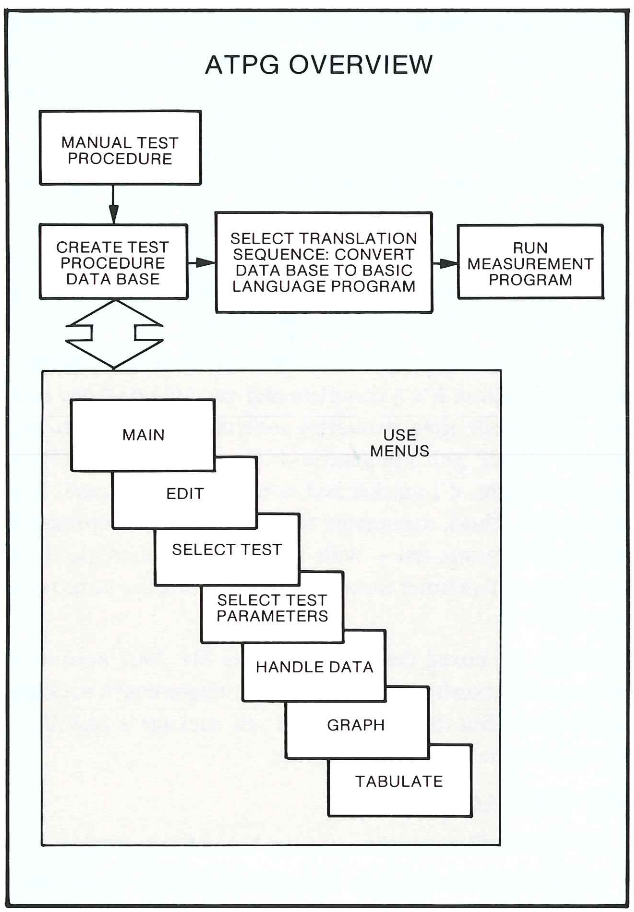


Fig. 1. *In an easy, menu-driven sequence, the MP 2902 lets you create a test procedure database and translate that into a ready-to-run BASIC-language program.*

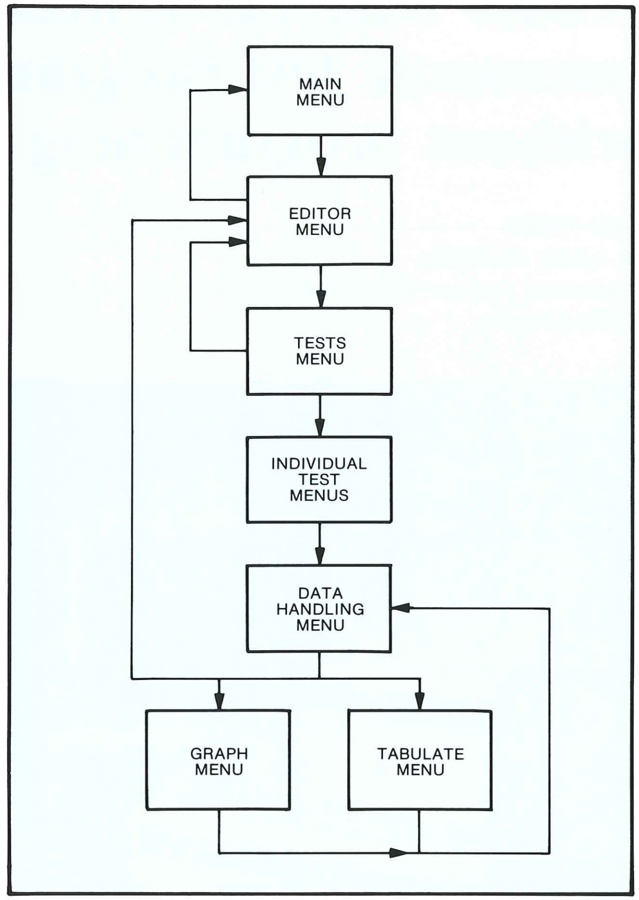


Fig. 2. *Developing automatic test procedures with the MP 2902 is done by choosing items on a series of menus. The main sequence shown here is typical. From the Main Menu, you first configure the system and then select the Editor Menu. On the Editor Menu, you tell the system you want to add a step to a procedure. When the Tests Menu appears, you select one of the 13 individual test menus. After you specify the parameters for the test, you can move to the Data Handling Menu. Here, you can select graphing or tabulation as the output form for the test data.*

Fig. 3. *This close-up of part of the Tektronix 4105 Computer Terminal keyboard shows the eight function keys (F1 — F8) used to select menu items.*

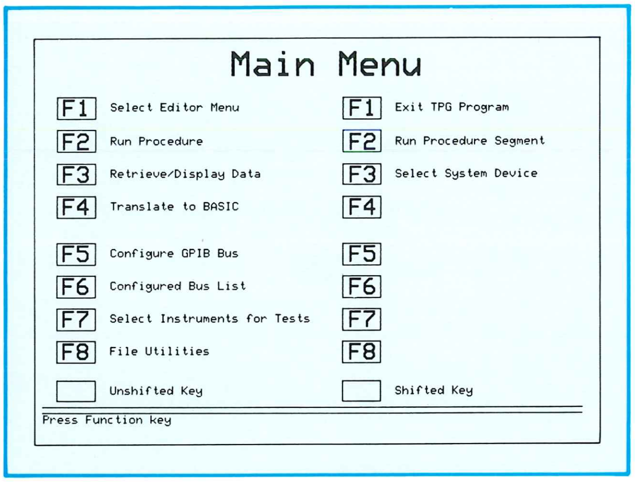


Fig. 4. *The Main Menu lets you select system configuration, translate an ATPG test procedure to BASIC, and perform other functions. By using the eight function keys either shifted or not, 16 choices are possible. The MP 2902 menus always list the unshifted choices in the left-hand column.*

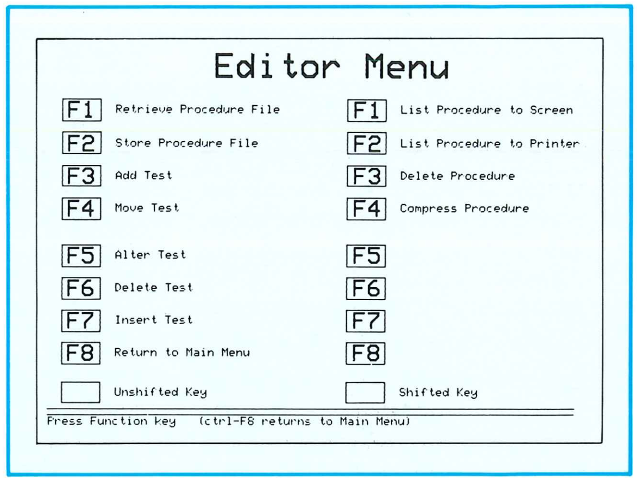


Fig. 5. *The Editor Menu offers choices of adding, deleting, changing, moving, or inserting tests. You also use this menu to retrieve, store, or list a test procedure.*

Audio measurement fundamentals

Most measurements in the audio and communications world are made below 100 kHz and fall into two broad categories: level and non-linearity. Level measurements include frequency response, gain/loss, noise level or signal-to-noise (S/N) ratio, power, and crosstalk/separation/isolation. Non-linearity measurements include total harmonic distortion (THD), THD plus noise (THD + N), individual harmonic distortion, intermodulation distortion (IMD; standards include SMPTE, DIN, CCIF).

All the measurements above except crosstalk/separation/isolation and individual harmonic distortion can be made directly with the MP 2902. The others can be made with the addition of a switcher (Tektronix MI 5010, SI 5010) and commercially available filters.

Most of these measurements are stimulus/response measurements; that is, a suitable stimulus is applied to the input of the device-under-test and the measurement is then made at the output. Some of these are single point measurements (power, noise level, distortion). Some are the ratio of two measurements (gain/loss, signal-to-noise ratio, crosstalk, separation, isolation). Many are sets of single-point measurements (frequency response, THD versus frequency, IMD versus level, power versus frequency, crosstalk versus frequency, etc.). It is very common to graph the results of the sets of measurements for further interpretation and analysis.

Much of the special vocabulary used by audio and communications workers relates to the dB (decibel). Since level measurements are common from several tens of volts on down to microvolts, the industry long ago standardized on using dB to express both absolute levels and ratios of signals. Frequency response is always "qX dB" from the midband level; signal-to-noise ratio is "X dB". In the broadcasting, recording, and satellite/microwave/telephone industries, absolute levels are also referred to in dB rather than volts or watts. The most common reference is one milliwatt. Levels referred to one milliwatt are expressed in dBm. Watts are clearly a power unit, but most level-measuring instruments are voltmeters (not wattmeters) and are not sensitive to circuit impedance. They must be calibrated for some particular value of impedance if they are to display dBm (power) even though they really measure voltage; 600 ohms is the most common circuit impedance in broadcasting and recording (150 ohms is also frequently used).

Most of the other special terminology is in the area of standard industry specifications. SMPTE is the Society of Motion Picture and Television Engineers. DIN is the Deutsches Institut fur Normalung, German standards. CCIR, CCIF. and CCITT are all French initials for European standards. IEC is the International Electrotechnical Commission. IHF is the Institute of High Fidelity Manufacturers and EIA is the Electronic Industries Association. SINAD stands for the ratio of (signal + noise + distortion) to (noise + distortion).

MP 2902 hardware

The MP 2902 Audio Measurement Package hardware consists of high-performance programmable instruments integrated into a versatile system. The specifications of this system are shown in the table below, and the block diagram outlines the hardware interconnections. As the diagram shows, the Tektronix 4041 System Controller is central to the system. The 4041's versatility allows it to offer tamper-proof operation for a production environment and a sophisticated tool for a product development team working on a complex product. The 4041's main central processing unit (CPU) is the 16-bit MC68000. Standard MP 2902 memory is 512 kilobytes of addressable memory. A Tektronix 4105 Computer Display Terminal and 4041 Opt. 31 Program Development Keyboard are also included in the MP 2902.

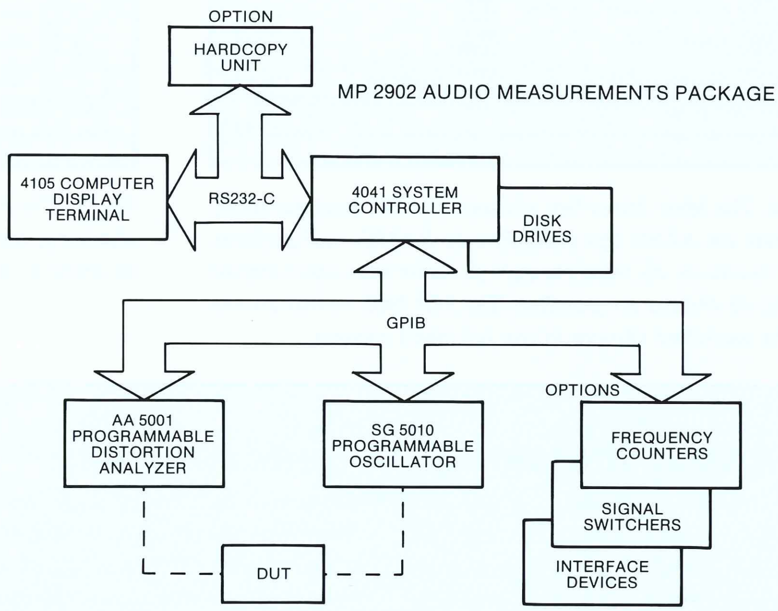
The AA 5001 Programmable Distortion Analyzer and the SG 5001 Programmable Oscillator pair up to perform such industry standard tests as:

- Harmonic distortion to IHF A202.
- Intermodulation distortion to SMPTE TH 22.51, DIN 45403, IEC 268.3, and IHF A202.
- Frequency response to IHF A202.
- Noise or signal-to-noise ratio to IHF A202 (''A'' weighting filter complies with ANSI specification S1.4 and IEC specification 179 for sound level meters).
- Noise measurements to CCIR 468-2 and DIN 45405 (with an MP 2902 option).

The AA 5001/SG 5010 pair ensures extremely low residual noise and distortion, permitting measurements on top-grade professional and consumer equipment. To match all types of audio equipment, the pair provides fully balanced analyzer input, balanced or unbalanced oscillator output, floating or grounded, 50/150/600 ohm.

With these units, you can select synthesized frequency stimulus to four or more digits with 0.01% accuracy. To accommodate many measurement standards, you have a programmable choice of filters and detectors. You can use the SG 5010's high-level oscillator output to test headroom and clipping thresholds of line level devices.

Besides all these features, the AA 5001/SG 5010 pair includes ten nonvolatile generator setups, and offers burst, squarewave, and amplifier modes.



The major components of the MP 2902 Audio Measurements Package include a terminal screen and keyboard, system controller, distortion analyzer, and oscillator. A wide range of hardware and software compatible measurement units and peripherals are available as options.

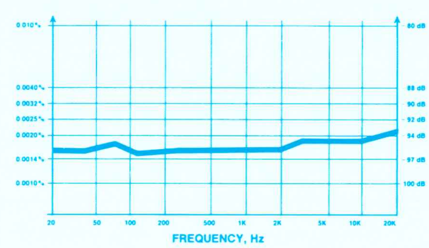
MP 2902 Package Specifications

Harmonic Distortion Function
Measurement Settling Time: Typically ≤2.5 seconds above 100 Hz, increasing by approximately one second per octave below 100 Hz.

Residual THD+N: (V_{in} ≥250 mV, RMS response, all distortion, noise, and nulling resources combined):

20 Hz to 20 kHz ≤0.0032% (−90 dB) with 80 kHz filter

10 Hz to 100 kHz ≤0.01% (−80 dB) no filters.



Typical System Residual THD + NOISE
(V_{in} ≥250 mV with 80 kHz filter, RMS response).

Intermodulation Distortion Function
Measurement Settling Time: Typically <2 seconds.

Residual IMD: (V_{in} ≥250 mV, RMS response)
SMPTE and DIN tests
≤0.0032% (−90 dB) for 60 Hz and 7 kHz or 250 Hz and 8 kHz, 4:1 ratio.
CCIF difference frequency test
≤0.018% (−95 dB) with 14 kHz and 15 kHz.

Level Function
Measurement Settling Time: Typically <2 seconds.
Flatness: ±0.1 dB 20 Hz to 20 kHz.

Environmental
Temperature Range: 0°C to +50°C.
Humidity: Up to 95% RH to +30°C.

Step 1: The Main Menu and starting point. When you load the system software, the Main Menu (Figure 4) appears. Because you are building a procedure, you first configure the bus (so that the controller knows what instruments it's controlling) by pressing function key F5.

Step 2: The Editor Menu. The next step requires the Editor Menu, which lets you add, delete, and change steps in a procedure. To get to the Editor Menu (Figure 5), just press F1. From here you can create (or in reality, "add") the first step of your test procedure by pressing F3.

Step 3: The ATPG Tests Menu. The Automatic Test Program Generator (ATPG) asks you for the number of this step. You press RETURN (because the default is "step 1"), then the Tests Menu appears. For our example, the first test is frequency response. With the Tests Menu (Figure 6) on the screen,

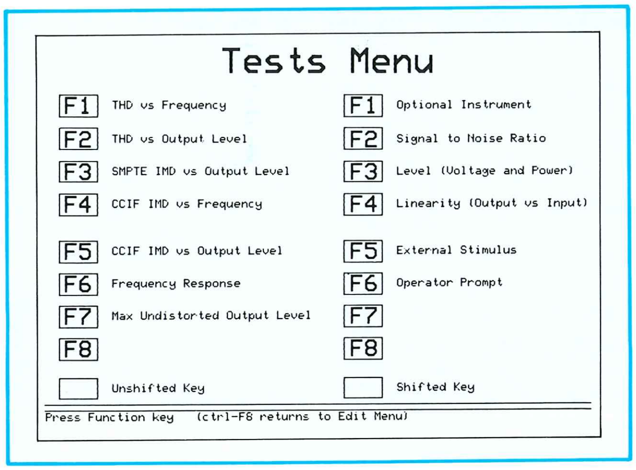


Fig. 6. *From the Tests Menu you choose audio tests, and you may also elect to include operator prompts in the automatic test procedure.*

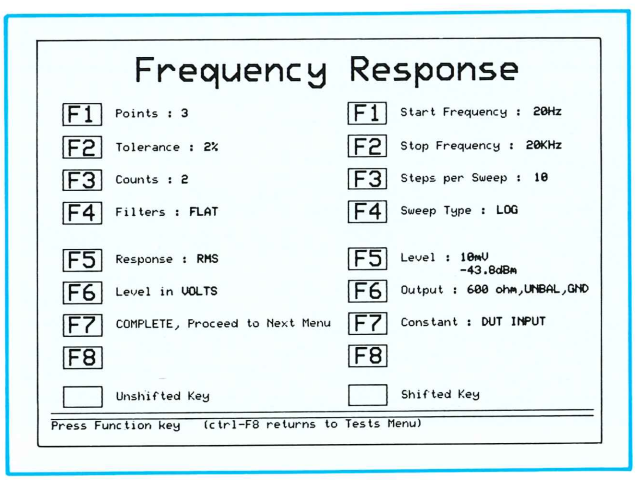


Fig. 7. *This menu is one of the individual test menus for selecting parameters. A colon is used to separate the function name and the default value — or the last value selected. Data handling is also selected from here.*

press F6 to select the Frequency Response Menu (one of 13 individual test menus).

Step 4: Test parameters. Now with the Frequency Response Menu (Figure 7) on the screen, you set the parameters. For example, you press SHIFT F5 to select the signal voltage level for the test.

Another selection might be 30 steps per sweep: Press SHIFT F3, type "30", and press RETURN.

For our example, let's decide to leave the other parameters at their default values and press F7 to go to the Data Handling Menu (Figure 8).

Step 5: Data Handling menu. Here you can tell the system that you want to graph the data, put it in a table, and store it. Let's graph it: press F1. The Graph Menu (Figure 9) appears. It lets you build and title your graphs.

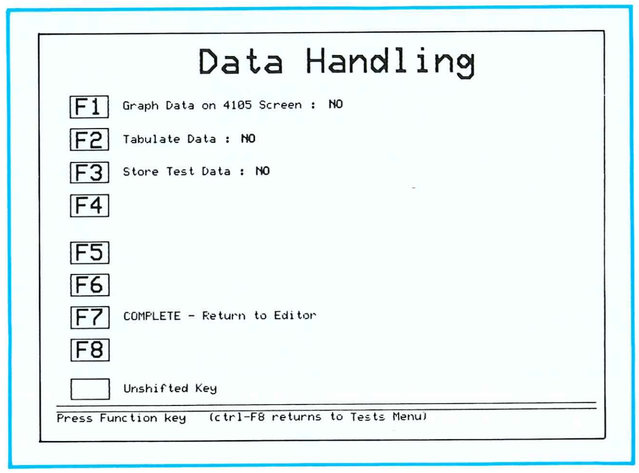


Fig. 8. *Once the tests have been run, the Data Handling is the menu to use to select a way to process the data: graph it on the screen, print it in tables, or store it.*

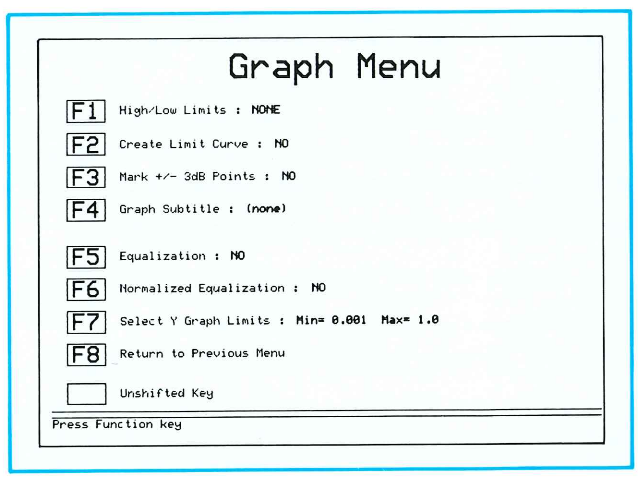


Fig. 9. *The Graph Menu offers selections for setting test limits, creating a limit curve, marking 3-dB points, and selecting equalization curves.*

MP 2902 tests

The MP 2902 hardware and software are tightly integrated, and the menu approach is flexible. Combining these opens the door to a wide choice of audio measurements. Typical applications include the following:

- Medium- to high-volume production line testing of consumer and professional equipment.
- In engineering laboratories, rapid characterization of complex variable devices such as parametric equalizers.
- Testing audiotape recorders and the audio channels of videotape, cassette, and disc machines — without requiring special synchronization.
- Testing earth stations and radio networks, with a remote signal source.
- Automating radio and TV broadcasting proof-of-performance tests (even running them daily at sign-on and sign-off).
- Testing very complex devices, such as large recording consoles with multiple inputs and outputs, or large audio switchers that would be too difficult to test manually.
- Characterizing loudspeakers and microphones, by adding reference transducers and preamplifiers to the MP 2902.

You can also automate a variety of specific audio measurements:

IMD measurements. You can perform SMPTE-like IMD measurements at various low frequencies and at any higher audio frequency. You can choose an amplitude ratio of either 1:1 or the standard 4:1.

CCIF tests. CCIF tests for transient or dynamic intermodulation (TIM and DIM) at frequencies near the DUT's upper band limit are simple to perform with the MP 2902.

Power computations. You can compute power from a voltage measurement across a known load resistance.

SINAD measurements. By modifying the BASIC measurement program, you can add an RF generator to make SINAD measurements of FM communications receiver sensitivity.

Noise and distortion measurements. Your program can select filters in the AA 5001 Programmable Distortion Analyzer. This selection lets you choose bandwidth for distortion measurements and weighting for noise measurements or for removing interfering signals.

The MP 2902 extends other measurement capabilities too. For example, you can make a signal compatible with the SG 5010 Programmable Oscillator output amplifier circuitry. (The SG 5010's output circuitry is high-level, multiple-impedance, balanced, and floating.)

Step .... With only about a dozen function-key keystrokes, plus typing in a few words and numbers, you have set up a frequency response measurement. At this point you can add more measurements to your procedure. Besides adding steps, you can also insert operator prompts that the system will print or display to remind the operator to take some action. Figure 10 shows an example of a graph produced after a test has been run.

After adding steps, you store the test or series and then run it. The run procedure asks you for a DUT ID number and your name so that you can identify the data later.

The last step: translating the procedure to BASIC.

You can run your test procedure in either of two forms:

- The program you created with the ATPG.
- A BASIC program translated from the ATPG program.

Translating the ATPG test program database to 4041 BASIC gives you the ability to customize your audio testing. The translation process uses the Main Menu to set file names for the program and for the data files and to prompt you to enter some more information that the translation process needs.

The translated BASIC program is complete. It automatically includes the utility routines necessary for data logging, graphics, and other operations.

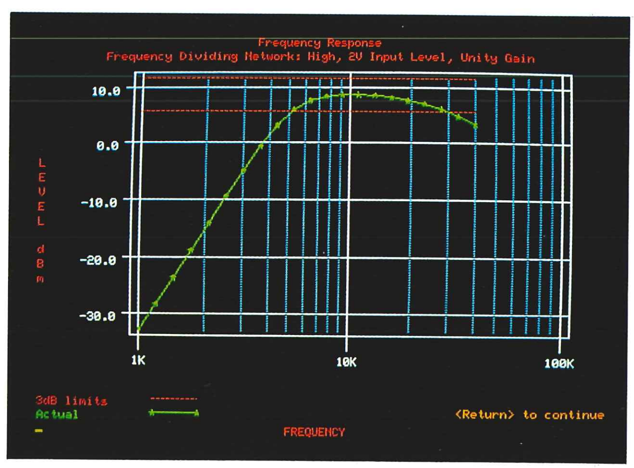


Fig. 10. *In this example graph shown on a Tektronix 4105 Computer Terminal, the MP 2902 plots a frequency dividing network's frequency response. The dashed lines represent the q3 dB points at a 10-kHz reference frequency. The graph subtitle was specified when the test was created.*

Running the BASIC version of your test procedure is easy too. You need only load the program, answer some identification questions, and respond to the prompts at the end of each test step.

Conclusion

If you have the need for state-of-the-art audio testing, you can get more information about the MP 2902, by calling your local Tektronix Sales Engineer or the Tektronix Sales Representative for your country. To receive an MP 2902 data sheet, use the reply card in this issue of **HANDSHAKE**.

Customer training seminars

For the convenience of Tektronix system customers with application or operational training needs, here is the early 1986 Tektronix IG Customer Training schedule.

CLASS	LOCATION	DATES
Waveform Processing with the 7854 Digital Storage Oscilloscope	Boston, MA	April 23-24
	Beaverton, OR	May 6-7
	Chicago, IL	May 20-21
	Boston, MA	June 4-5
	Orlando, FL	June 18-19
Advanced Waveform Processing with SPS BASIC and the 7912AD/7612D	Beaverton, OR	April 28-May 2
	Washington, DC	May 19-23
	Philadelphia, PA	June 16-20
Advanced Digital Storage Measurements, using the 2430 150-MHz Portable Digital Oscilloscope	Santa Clara, CA	April 24-25
	Boston, MA	May 7-8
	Orlando, FL	June 18-19
Basic Digital Storage Measurements, using the 100-MHz 2230 Portable Digital Oscilloscope	Santa Clara, CA	April 23
	Boston, MA	May 6
	Orlando, FL	June 17
Parametric Measurements using the 2445/65 Oscilloscope	Boston, MA	May 6
	Philadelphia, PA	June 4
Advanced Parametric Measurements using the 2465 Oscilloscope	Boston, MA	May 7
	Philadelphia, PA	June 5
Digital Storage Fundamentals	Santa Clara, CA	May 6-7
	Washington, DC	June 3-4
Digital Waveform Processing Fundamentals	Santa Clara, CA	May 6-7
	Washington, DC	June 3-4

To register for these seminars, call IG Customer Training, 503-642-8013, or to find out more, contact your local Tektronix Field Office.

Digital pulse-echo techniques for advanced composites

John L. Cline
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Pulse-echo ultrasonics is an effective NDE (non destructive evaluation) tool. It provides useful information about material properties and hidden defects. Space-age materials such as advanced composites provide a challenge to conventional ultrasonics because of their non-homogeneous and anisotropic nature. (Measurements taken on anisotropic materials differ depending on the orientation of the material or measurement.) The resulting waveforms have varying degrees of time and amplitude information.

A digitizing, controller-based test system capable of acquiring, recording and analyzing hundreds of ultrasonic waveforms per hour and storing them on magnetic disk for computer analysis has been designed. The test system is transportable and has been used at the factory, test bed, and operation site locations.

This paper discusses system design, software and hardware development, equipment reliability, and digital data presentation concepts.

Non-Destructive testing/non-destructive evaluation of composites

Composite materials such as fiberglass, phenolics and carbon-matrix resins, are rapidly replacing metals in many aerospace structures because of their weight savings and great strength. These materials are subject to manufacturing flaws and handling damage which may occur inside the material and cannot be detected visually.

Critical applications of composite materials include airplane radome housings, control surfaces and brake shoes for aircraft, and rocket nozzle exit cones.

Rocket nozzle cones are especially fragile and considerable internal structural damage may be sustained from mishandling during the construction phase, or during transportation to final assembly and test areas.

The need to inspect these materials by non destructive evaluation techniques clearly exists.

Solids versus composites

Examples of composite materials that are difficult to test ultrasonically are low density fiber-reinforced plastic and carbon-carbon composites. Greater demands are put upon the test system components, such as the pulser and receiver, than with homogenous solid materials. Figures 1a and 1b show

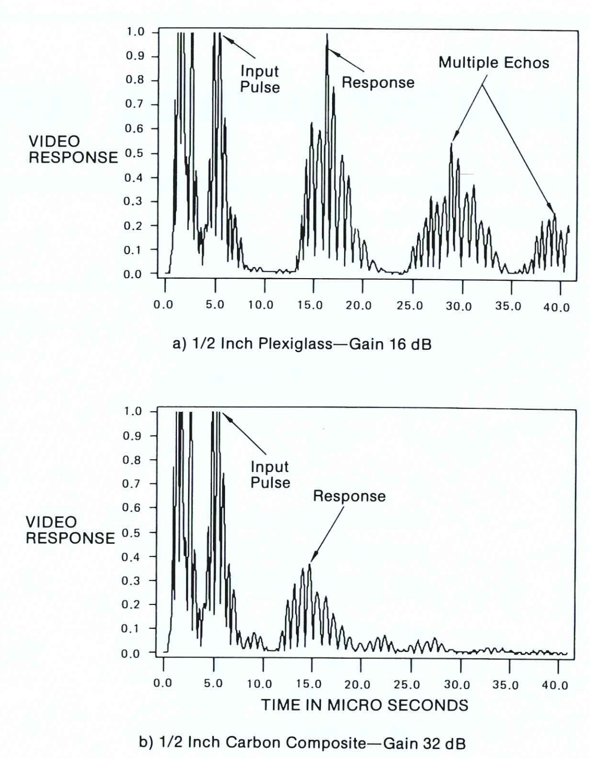


Fig. 1. *Ultrasonic attenuation in composites.*

response signals in both a one-half-inch (13 mm) plexiglass block and in a one-half-inch piece of carbon composite. The ultrasonic response in the composite material is down 15 dB from that of the plexiglass. This illustrates the difficulty in surface-coupling and the high attenuation characteristics of the composite matrix.

Pulse-echo ultrasonics

The three common ultrasonic techniques that were considered in this program are:

1. Through-transmission, with a transmitter on one side of the material and a receiver on the other.
2. Pitch-catch, with a separate transmitter and receiver co-located on the same side.
3. Pulse-echo, the method used in this discussion, requires only one transducer which both sends and receives.

A pulse-echo system was chosen for development because it can be used on materials where the back side is not accessible. This is quite often the case in assembled aerospace structures. Figure 2 illustrates these three ultrasonic techniques.

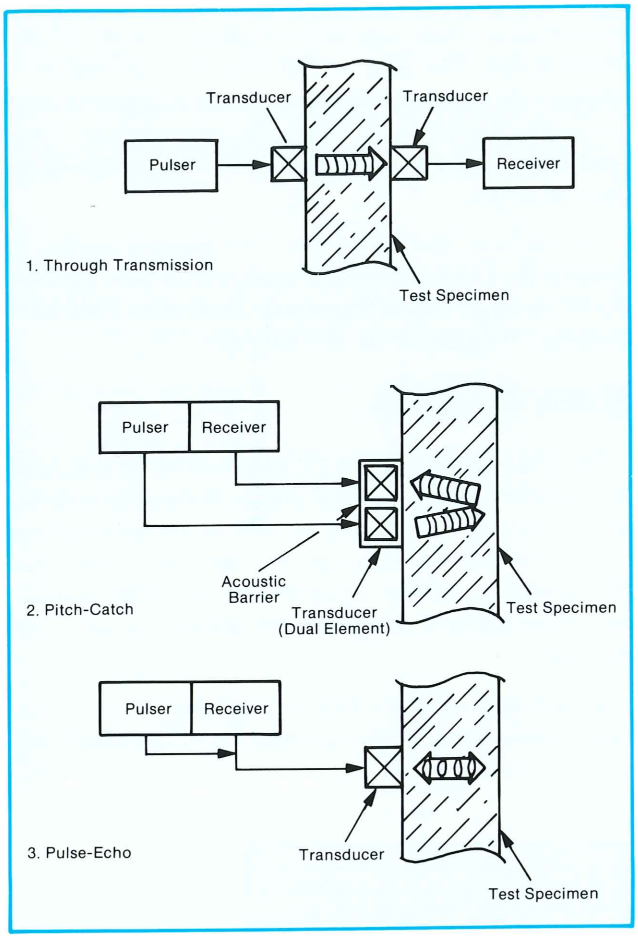


Fig. 2. *Three common ultrasonic inspection techniques.*

A pulse-echo system requires a high voltage (200 to 600 V) pulser, a transducer with a piezoelectric element cut to the required frequency, and a sensitive receiver (40 to 80 dB gain). The receiver, connected directly to the pulser output and the transducer, handles the high pulser voltage and yet is able to detect the millivolt level data contained in the returning echo.

Coupling to the test surface

The transducer is coupled to the test surface by means of a thin layer of liquid. When the transducer is stimulated by a high-energy pulser voltage, it converts electrical energy into mechanical oscillations by the piezoelectric effect. A compressional waveform then passes into and through the material to the opposite surface where it is reflected back to the transducer. The transducer converts this vibratory energy into a high-frequency (RF) electrical signal which is passed into the receiver for detection, amplification, and filtering. The resulting video signal contains a truncated main excitation pulse and the reflected wave. A simplified pulse-echo system is shown in Figure 3.

Figure 4 illustrates three ultrasonic test properties that may be used to classify materials. A strong return signal or backface echo at the proper time (T_B) is indicative of uniform, good quality material. Internal cracks, voids, laminations, and dry plies will interrupt the normal through-back transit resulting in a strong, early return signal.

The amplitude and time of the returning signal therefore provides an indication of material quality and is the means by which ultrasonics becomes a material evaluation technique.

Pulse-echo systems: digital versus analog

Conventional or non-digitized ultrasonic data does not lend itself well to analysis. Hardcopy data must be produced by Polaroid™ camera or X-Y plotter. Simple time-history plots, when taken in quantity, must be interpreted and reduced by

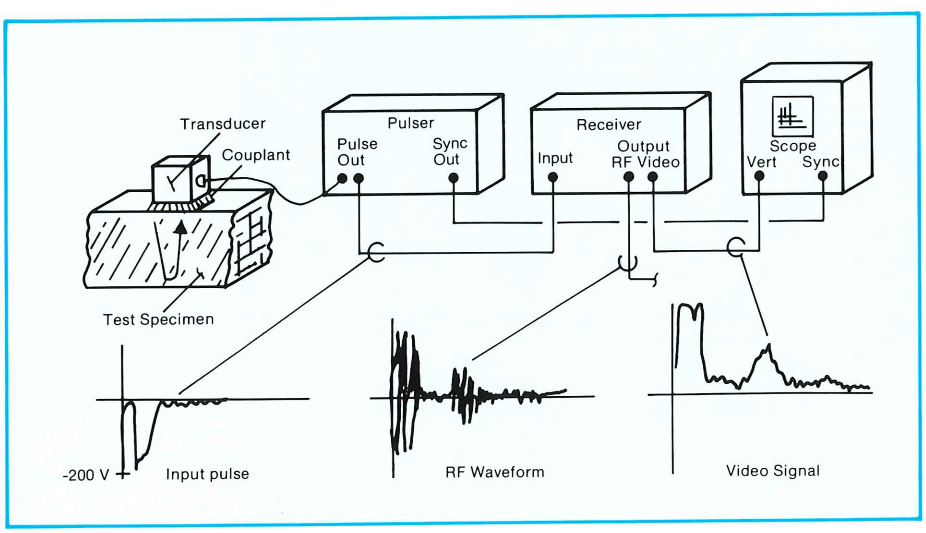


Fig. 3. *Simplified pulse-echo system.*

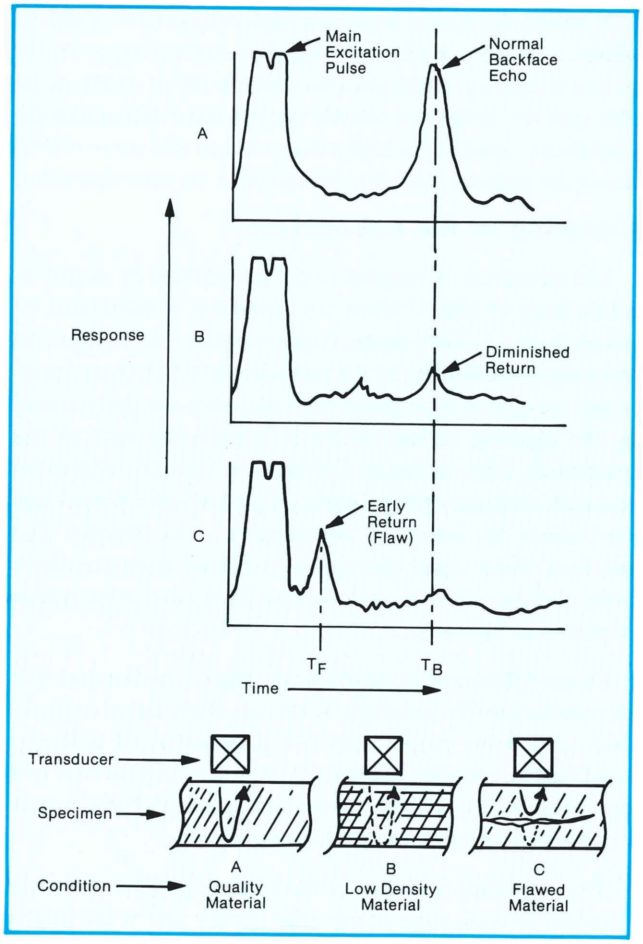


Fig. 4. *Ultrasonic test properties.*

hand. Statistical or population studies employing thousands of waveforms are virtually impossible.

On the other hand, when signals are digitized, stored, and processed by a computer-based system controller with disk memory, large quantities of data are assimilated, intelligently acted-upon, neatly annotated, tabulated, and plotted for instant review. This kind of real-time data can then be a reference. As the standard production data on manufactured composites, it might consist of population histograms, video waveforms, tabulated peak amplitudes, and corresponding times of arrival.

The digitized data, once stored on magnetic media, is available for a variety of off-line analysis programs. An IBM PC-XT, or larger Digital Equipment Corporation VAX-sized computer, is employed for this purpose.

System description

The DPE (digital pulse-echo) system described in this paper is a modular, transportable ultrasonic test system utilizing menu-driven software. It may be used on any material that is amenable to ultrasonic inspection. However, the software is designed specifically for taking discrete, hand-held ultrasonic data over a matrix of points on highly attenuating composite materials.

A block diagram of the DPE system is shown in Figure 5. Figure 6 shows the physical arrangement of the system and a conical test specimen.

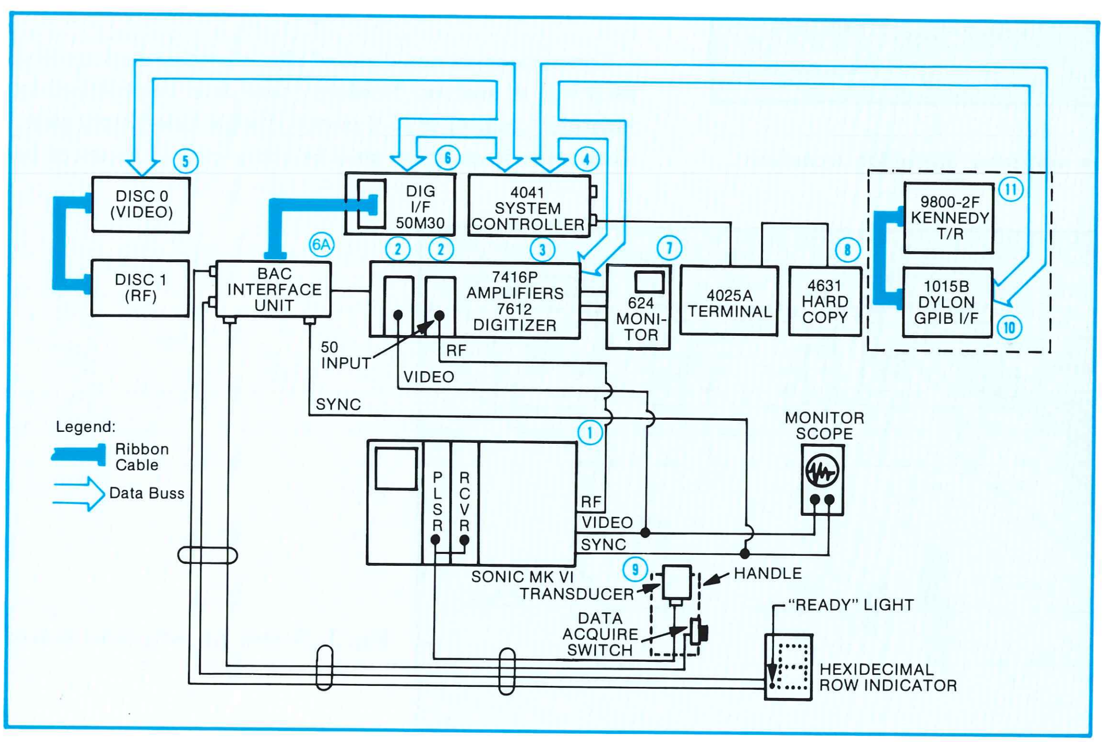


Fig. 5. *Equipment connection diagram.*

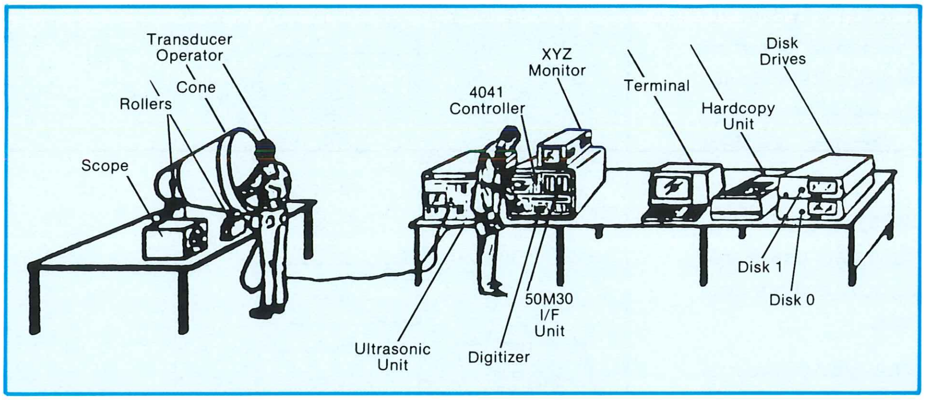


Fig. 6. *Digital pulse-echo system arrangement.*

Ultrasonic equipment

An Ultran WC 50-10 transducer and Sonic Mark VI high-performance ultrasonic flaw detector were selected to meet the challenge of composite material testing. The Sonic Mark VI consists of two basic components: a 300-volt square wave pulser, and a high gain receiver/amplifier.

Transducer. The transducer selected has a broad bandwidth and short pulse width. It has a 13-mm diameter lead meta-niobate piezoelectric crystal element cut to a nominal 1.0 MHz response. This frequency produces optimum results in carbon composites of 10-mm to 13-mm thickness. The transducer has a direct contact face and is designed to be hand-held.

Pulser. The pulser, a model PG062, supplies a square wave pulse of adjustable width and level. The pulse width is normally adjusted to 0.5 microseconds (half the period of the 1.0-MHz signal the transducer is tuned to, because a full cycle would damp the return signal). A negative square wave pulse adjustable from 50 to 300 V peak into 50 ohms is supplied to the transducer/receiver interface as shown in Figure 3.

Receiver. The model RE 063A receiver is operated at 1 MHz. A gain of 30 dB is required for composites up to 15 mm thick. A gain of up to 90 dB is available for thicker specimens.

Digital hardware

Most of the digital hardware is shown in Figure 7.

Digitizer and programmable amplifiers. The digital hardware consists of two Tektronix 7A16P Programmable Amplifiers which are plugged into the Tektronix 7612D Programmable Waveform Digitizer. The mainframe digitizer has an extremely high — 200 MHz — clock rate which is adequate for the highest ultrasonic frequencies required in composite testing.

Waveform digitizing is controlled by a conditioned sync pulse from the pulser in the ultrasonic unit which is set to a nominal 300 pps (pulses per second) rate. (System operation is virtually independent of the pulse rate which is mainly adjusted to provide good screen brightness.)

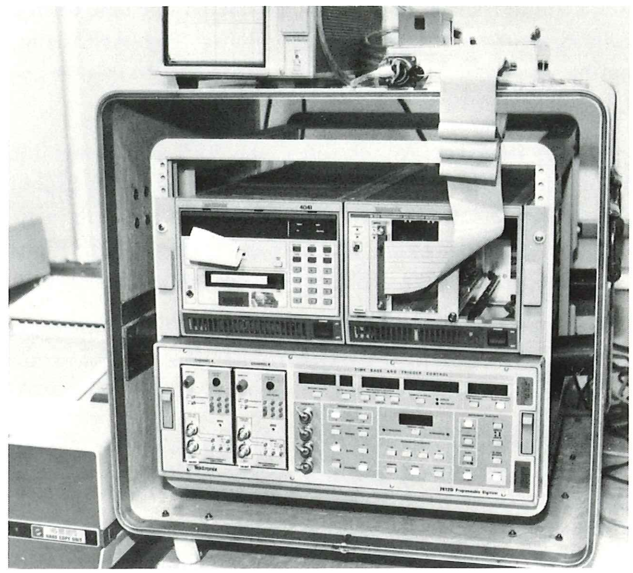


Fig. 7. *Pulse-echo system hardware.*

Monitor. A 2-channel Tektronix 624 General Purpose Waveform Monitor (top unit in Figure 7) provides an instantaneous view of each digitized video and RF waveform. The screen conveniently displays and holds the images for inspection until a new waveform is taken. In the event that improperly-taken digitized waveforms appear, the data is re-taken.

A typical video waveform taken off a 15 mm-thick composite is a rectified 1 MHz signal with a 40 microsecond wide display window as shown in Figure 1b. The required digitizer sample time is 80 nanoseconds and the record length is 512 bytes (words). Figure 7 shows the Tektronix 7612D digitizer with these settings displayed.

System controller. The Tektronix 4041 System Controller Option 01 is a programmable microcomputer with the ability to control instruments and data flow over two IEEE-488 output ports. These instruments include the digitizer, floppy disks, general purpose interface bus (GPIB) boxes, and the magnetic tape. One of the ports is a (DMA) Direct Memory Access high-speed port. Two RS-232-C serial ports are also available.

The 4041 as used has 160 kilobytes of RAM (random access memory) and is normally loaded by programs stored on cartridge tapes. The 4041 also has the following ROM (read-only memory) packages: graphics, plotting, signal processing, and program development (4041R01 through 4041R04 respectively).

File management system (Tektronix 4907, Opt. 30). Two 8-inch floppy disk drive units file and retrieve data under program control. They have a 1.2 megabyte capacity and can store approximately 2,000 ultrasonic waveforms.

Tape recorder. The Kennedy 9800 8-inch tape recorder is rack-mounted in a transportable container. It is used primarily in the lab to transfer data to a VAX-compatible tape format following a test. A Dylon 1015B unit, an IBM/ANSI compatible magnetic tape controller, is needed to match the IEEE-488 GPIB bus data to tape input.

Digital interface. A Tektronix MI 5010 Programmable Multifunction Interface with a 50M30 Programmable Digital Input/Output Card in conjunction with a Boeing-built interface unit described below provides additional I/O functions which improve testing efficiency and reliability.

The MI 5010 and 50M30 processors derive their power from a TM 5003 Power Module Mainframe. The processors are software-controlled by the 4041 controller using the GPIB.

The 50M30 is connected to the Boeing unit via a 50 conductor ribbon cable as pictured in Figure 7.

BAC interface unit

The BAC (Boeing Aerospace Company) interface unit performs the following three functions:

1) It allows remote initiation of data acquisition (the terminal is bypassed) which is required if the operator is working in a hard-to-reach place.

2) It allows a hexadecimal display of the current row number to the transducer operator.

3) It tells the operator, by extinquishing an LED decimal point on the display, that the system is acquiring data and that the transducer must remain steady momentarily. When the row number and decimal point reappear, the system is ready for the next data point.

Interface system description. When the data system is ready for a set of waveforms, the 4041 sends three commands to the MI 5010 and the 50M30. The first clears or resets the handshake lines. The second arms the service request (SRQ). The third command resets the flip-flops in the BAC interface unit and sends the row number to a hexadecimal display.

In the BAC interface unit, the switch (a normally open, momentary-contact device) is enabled. The flip flop that uses the switch to change its state also drives the decimal point LED

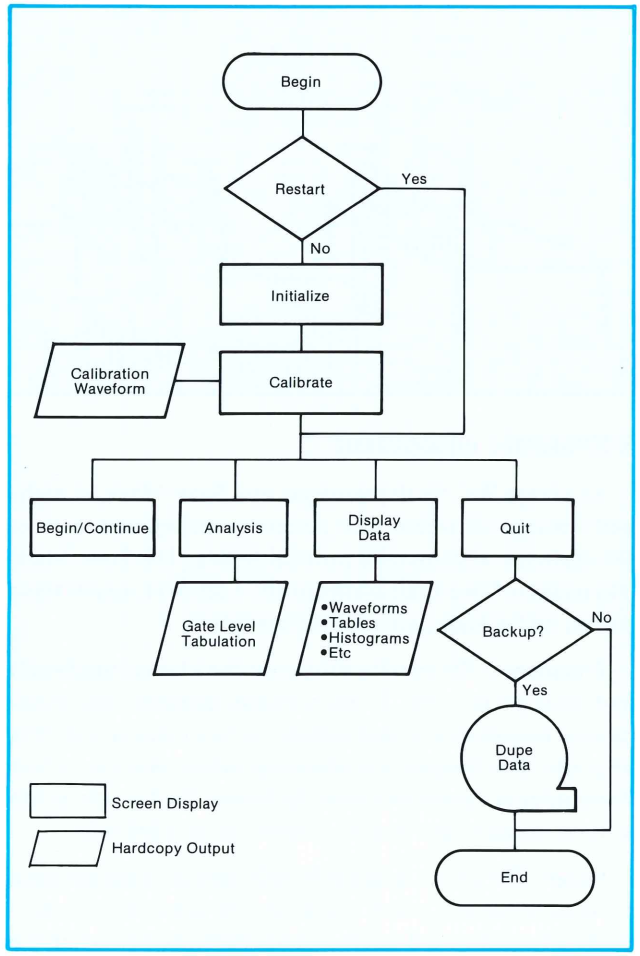


Fig. 8. *Flow diagram.*

in the hexadecimal display logic. When the switch is depressed, the flip-flop changes state, turning off the LED and sending a signal to the 50M30 triggering the SRQ on the GPIB. The 4041 then triggers channels A and B on the 7612D digitizer and the video and RF signals are acquired. After the waveforms are transferred to the 4010, it sends a disable command to the BAC unit through the 50M30, changing the state of the other flip-flop, which blanks the display logic. This tells the operator that he can now move to the next data point.

In addition to the above, the BAC interface unit provides signal conditioning for the sync pulse by using 50-ohm line drivers into the low impedance sync input of the digitizer.

Software development

Beginning with a program flow diagram (see Figure 8), a workable BASIC software package was developed in approximately four man-months. This program initially contained about 800 lines, and grew to its present size (revision F) of over 1200 lines with considerably more features and speed than the original version. The program coding is approximately 50% data I/O, 40% error trapping, and only 10% computational. The program is written in 4041 BASIC, an extended BASIC language adapted to data-handling applications.

The system in operation

The DPE test system finds equal use in the lab as in field locations. Test specimens may be brought to the Boeing Nondestructive Evaluation Lab and tested there; however, because of shipping risk, size, or scheduling limitations, the test system will more often be taken to the test site. Disassembly and packing of the equipment for flight requires only about 30 minutes and in most instances, the equipment travels on the same plane as the test personnel.

Waveform acquisition

Data taking requires that the software appropriate for the specimen under test be loaded into the 4041 controller via cartridge tape. Initialization values are then entered and system end-to-end calibration is performed under program control.

Calibration is performed using a transducer on a selected phenolic block standard. The resulting time-of-arrival and back-face echo amplitude are similar to that of the test material. Tolerances of up to 5% are allowed; however, in practice less than 2% variations are observed in time and amplitude. Calibration is performed before, during, and after each test. Gain changes are made to compensate for system drift, generally less than 1 dB.

Figure 8 illustrates the program options and flow.

Following calibration, the transducer operator moves to the test specimen area where he monitors and controls all aspects of the test using remote indicators and a data-acquire switch.

The program begins by normalizing all data to the calibration value. The program acquires data points serially and is self-stepping; starting at Row 1, Column 1, and Sector 1, and acquiring a waveform, moving to Row 1 Column 2, and so on until the last waveform is taken. Alternate starting points are allowed but they must be keyed into the program. Any previously-taken waveform which is questionable may be replaced by a new waveform at any time.

Waveforms taken for each location on the test specimen are windowed according to the expected specimen thickness or time-of-arrival. A maximum-value-seeking algorithm selects the peak response within the window for each test location. These, windowed, maximum values constitute the data base on which all quick-look data analysis is performed. Data are accumulated in memory and transferred to disk in groups of four waveforms (one row) at a time.

Data presentation

The acquired data must be analyzed and presented in meaningful and easily-interpreted form. The following field data (Figures 9 and 10) have been produced by the Tektronix 4041

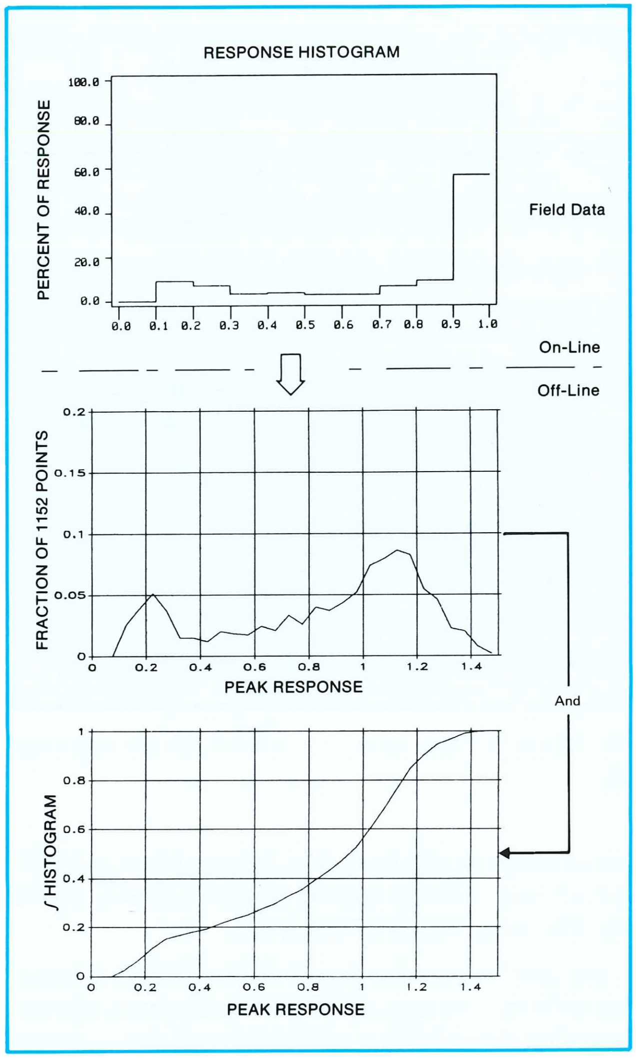


Fig. 9. *Offline data analysis — histograms.*

controller using its graphics ROM package and the remaining data by the lab-based IBM PC-XT and/or a DEC VAX-11/750 computer.

Quick-look or field data (consisting of back-face echo maximum values) are presented as normalized peak values, time-of-return values, gate-level values, and shaded plots (a 30-dB range divided into four gate levels), as well as response histograms. These simpler data products do not require extra calculation time and, in general, are adequate for an initial assessment of the test specimen.

Much more comprehensive and interesting evaluations of the data are obtained off-line using lab-based mini and micro-computers. Figure 9 presents Tektronix 4041 and VAX/VMS-generated histograms. The integral histogram has proven useful as a unique specimen signature for population studies.

Figure 10 shows an example of a shaded density amplitude plot that is obtained in the field. In addition, a multi-shaded

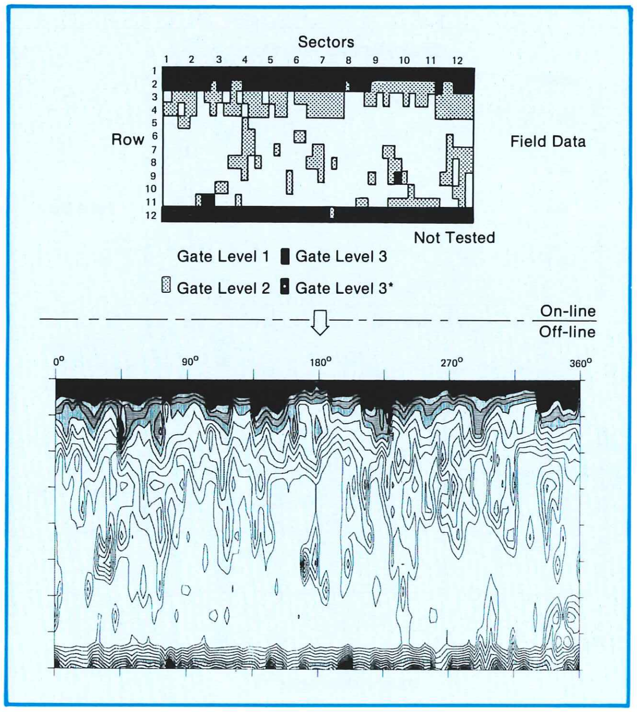


Fig. 10. *Offline data analysis — shaded density amplitude plot.*

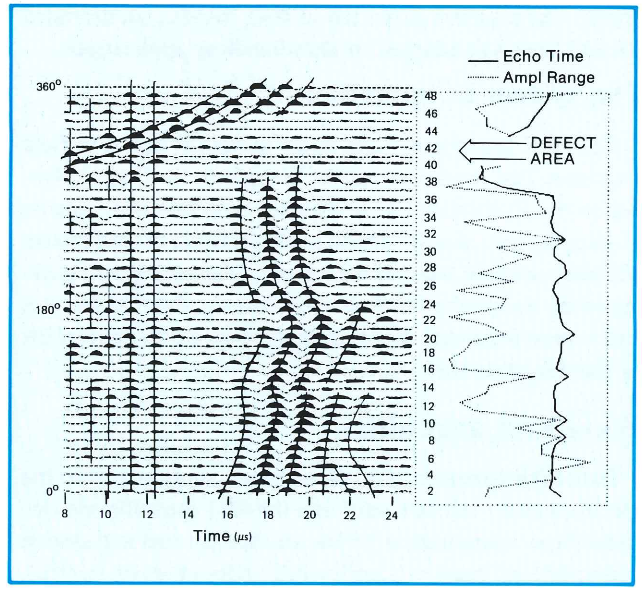


Fig. 11. *Modified B scan for fault location.*

plot of windowed peak amplitudes, performed back in the lab, is also shown. This demonstrates the improvement in shaded plot data using the VAX/VMS system.

The field data has only four levels of amplitude information while the highly-processed, off-line, lab data is smoothed and has fifteen levels of information and consequently is more useful.

Figure 11 is IBM PC-processed RF data. Figure 11 is a modified B scan with 48 RF waveforms windowed between 8 and 24 microseconds representing a single row of data. The hidden defect is easily located because of a major shift in the time-of-arrival of the data.

System reliability

The DPE equipment has logged well over 10,000 air miles, hundreds of over-the-road miles, and considerable rough handling and abuse in between, and yet has never missed a scheduled test due to equipment failure. High quality transportation containers must be given some credit for this record. The DPE gear packs into nine custom-fitted, shock-isolated, fly-away cases. Figure 7 shows rack-mounted equipment with shock isolation support from the sides of the container.

The DPE equipment has experienced random failures which, as yet, are not predictable. However, failures seem to occur more frequently in a factory environment where power fluctuations and spike transients abound. A restart memory option, saving all data for easy recall in the event of a system crash, is mandatory.

A few failures have occurred with the terminal console which were quickly traced to replaceable plug-in circuit boards. These boards seemed to loosen at their plug-in base due to transport. The remedy was simple replacement or to clean the contacts of the boards repeatedly, and to ensure, by inspection, that each board was well-seated prior to equipment power-up.

The cartridge drive of the controller was replaced early due to intermittent operation and has worked well since then. The only other critical mechanism, the floppy disc drives, have operated without a problem.

Expanding the system

Memory. The system speed which was initially software-limited, is now hardware-limited.

Data transfer time to disk is currently 8 seconds per row (4 waveforms) which, in a 360-row program, amounts to almost an hour of accumulated wait time.

This time could be quartered by increasing data transfer rates with a 10-megabyte hard disk system now under consideration. Such a system would also permit automated data-scanning speeds such as that encountered in through-transmission water-bath inspections using a robotic arm.

Test location navigator. Positional information of the transducer on a test specimen is usually difficult to obtain. Internal conical surfaces, where no marks of any kind are allowed, are especially difficult to map accurately. Repeatability of ultrasonic data is compromised by the inability to place the transducer in exactly the same spot as that of a previous test. An accurate position encoder/indicator would be very useful.

Various positional navigating systems and robotics which encode and read out the coordinates over a test grid are under investigation.

Conclusions

The digital pulse-echo system is new and is still undergoing hardware and software refinements. The official software version at the time of this writing is Revision F and holding.

Refinements in technique continue also. A nylon jacket was added to the transducer when it was noticed that hand heat affected system response by a few dB.

The DPE system described herein works well for its primary NDE applications — ultrasonic inspection of composite material for delamination and damage.

The DPE system is well suited for field operation because of its portability, ease of setup, and nearly foolproof operation. For example, there are 16 digitizer and 10 programmable amplifier controls which are set during each initialization by the operating program and consequently are not subject to human set up error.

End-to-end calibrations, conducted before and during each test, ensure system accuracy and repeatability, essential to the evaluation and study of composite materials.

The primary applications for the DPE system is on Boeing programs where a broad ultrasonic data base is being established. Concurrent with this work, innovative data gathering, processing, and analyzing techniques are being pursued. In addition, the DPE system is finding increasing ultrasonic test applications in the laboratory in support of other types of material evaluation requirements such as epoxy composites and metals.

The DPE system is adaptable to other NDE disciplines such as acoustic emission and eddy current. A program for digitizing, storing, and displaying eddy current amplitude and phase data is being developed.

Reference

*Bhardwaj, C. Mahesh, **Optimum Ultrasonic Parameters for Low Density Composite Evaluation, October 1983, Ultran Laboratories, Inc., PA.***

This article is drawn from a paper presented to the International Instrumentation Symposium in San Diego in May, 1985.

New SYSTEK 7854 software available

SYSTEK 7854 is interactive system software that acquires, measures, and stores digitized waveforms on magnetic media. No programming knowledge or experience is required to use the system.

SYSTEK 7854 is self-configuring with automatic loading of controller programs. For example, when used with a 4041 without a graphics terminal attached, menus are displayed on the CRT of the 7854.

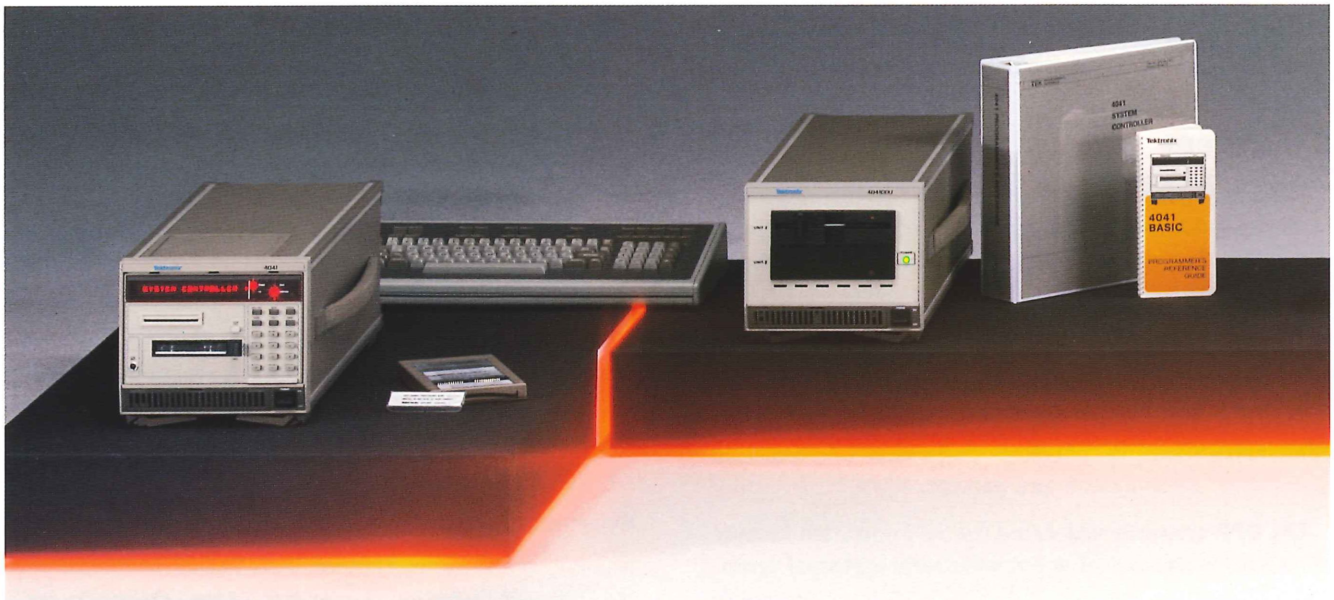
Self-configuration extends to processing capabilities as well. When the 4041 has 160 kilobytes of RAM and the 4041R03 Signal Processing ROM Pack, for example, the processing menu offers: taper waveform, Fast Fourier Transform, inverse Fourier Transform, segment waveform, differentiate waveform, correlate waveform, and convolve waveform.

SYSTEK 7854 is written in 4041 BASIC and requires a Tektronix 7854 Waveform Processing Oscillscope (with Option 2D, 4K Expanded Memory, and user-selected, 7854-compatible plug-in modules) and a Tektronix 4041 System Controller (with 32K bytes RAM minimum).

SYSTEK 7854 is priced at $400 (slightly higher outside the U.S.). If you want to find out more about this or other Tektronix software products, please contact your local Tektronix Field Office or the sales representative for your country. For information about these products, use the **HANDSHAKE** reply card included in this issue.

This software is also available through the Tektronix National Marketing Center. Call 1-800-426-2200, extension 440 (in Oregon, call 627-9000 collect). Order S49 F102, SYSTEK 7854; tell them you saw it in **HANDSHAKE**.

Tektronix 4041 Plus and 4041DDU



There's a new Tektronix 4041 Controller, and there's now a disk drive unit with both a 10-megabyte hard disk and a 5¼-inch floppy.

New Tektronix 4041 Controller

The new 4041 is better than ever, one measure of that is increased reliability while the price has decreased. Small to medium-sized ATE systems can use its 16-bit MC68000 processor, the integral printer and LED display, and Tek's 4041 BASIC — optimized for system operation — to great advantage.

Here are the changes to the Tektronix 4041 Controller:

- There's a new option: Option 10. It puts the power of graphics, plotting, signal processing, and utility ROM packs on the CPU rather than in the ROM tray. Option 10 is the equivalent — except that it costs less — of 4041R01, R02, R03, and R04, all of which are still available separately.
- The base 4041 now has 512 kilobytes of memory.
- Processing speed is up approximately 25% on the new 4041 — depending on the application.
- These commands (from the UTL2 softload ROM) have been added to the base language:

  ARRSEG - copy part of an array to another array
  GETARR - input an array in binary block format
  GETSCL - input an array in binary block format, and scale it
  ARRSCL - convert an integer array to a floating point array and add in scaling factors
  HISTOG - generate a histogram of an array

- There are now three, mutually-exclusive, configuration options for the 4041:

  Option 01 adds a second RS-232-C serial communications port and a second IEEE-488 interface port with DMA (Direct Memory Access) capability.

  Option 02 adds an 8-bit parallel TTL interface for custom control applications to the standard 4041.

  Option 03 adds a second RS-232-C interface and an SCSI (Small Computer System Interface) to let you use a 4041DDU.

New 4041DDU disk drive unit

If you like your magnetic media spinning — rather than threading its way past tape heads — the 4041DDU is for you. It includes a 10-megabyte hard disc drive, a 320-kilobyte floppy drive, a disk controller, and the power supply. The 4041DDU is in the same package type as the 4041, that means you can have a portable version with a handle and that you can use the same rack mounting kit so the two units can be racked together.

Speed and storage capacity are the main advantages over tape drives. Here are some transfer speeds as compared to tape:

Function	Transfer speed compared to tape	
	floppy disk	hard disk
READ	3.5 X faster	8.0 X faster
WRITE	4.5 X faster	15.8 X faster

The 4041DDU comes with this support software:

AUTOLD -	to start the checkout program
DDUCHK -	to check out a 4041DDU
BACKUP -	to back up the hard disk to floppy
COPY2 -	to copy files from one mass storage device to another (supports meta characters)
EXA1 -	example program
EXA2 -	example program

New measurement package pricing

As a consequence of the Tektronix 4041 Controller price reduction with this new version of the 4041, some Tektronix MP (measurement package) products that include a 4041 have also been repriced. The price changes are based on the 4041 reduction and a savings for including the optional 4041DDU. The products affected are MP 2101, MP 2201, MP 2401, MP 2501, MP 2901, MP 2902, and MP 2903.

Customer training available

A seminar geared to systems customers familiar with GPIB concepts and BASIC programming is available. The seminar emphasizes using the 4041 command set which includes instructions that make it possible to write nearly crash-proof code. Coding like this means that nontechnical operators can perform complex systems tasks without fear of stopping the 4041 controller with inappropriate input.

The three-day seminar's objective is to have you writing programs that take full advantage of the 4041. The emphasis is on: the 4041 as an instrument controller; the 4041 ROM packs (including signal processing, graphics, and other special purpose operations); array processing; and 4041 extended BASIC capabilities.

Contact your local field office for schedule and cost.

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 a data sheet describing the 4041 system controller and 4041DDU, use the **HANDSHAKE** reply card included in this issue.

New Library! New Programs! New Price!

There's a new library of programs available for Tektronix system users. Many of the programs in the Instrumentation Software Library are new, some are revised, but all are priced at $50 each (slightly higher outside the U.S.).

Programs in the Instrumentation Software Library include instrument utility software, measurement utilities, test program generators, and waveform analyzers — all at $50 apiece. Each program includes operating instructions and is supplied on the standard media of the instrument controller. Initial programs support the Tektronix 4041 System Controller, but other popular controllers will be supported in the near future.

Instruments supported by this library include:

- The Tektronix 7D20 Programmable Digitizer
- The Tektronix 7854 Programmable Waveform Processing Oscilloscope
- The Sony/Tektronix 390AD Programmable Waveform Digitizer
- The Tektronix 2445/65 Oscilloscope
- The Tektronix 2430 Digital Oscilloscope
- Most of the Tektronix TM 5000 family of GPIB Programmable Instruments
- With more instruments to be supported in the future

In addition, utility programs are available to aid in the use of the Tektronix 4041 System Controller along with the Tektronix 4105 Computer Display Terminal for system control.

A Summary of Available Programs

Here's a brief summary of the programs available from the Instrumentation Software Library at the time this issue of HANDSHAKE went to press. Since new programs are being added to the library almost daily, watch future issues of HANDSHAKE or request a copy of the Instrumentation Software Library catalog by checking the appropriate box on the HANDSHAKE reply card. The catalog also provides a more in-depth description of each program's operation to help in your software selection.

Catalog Number	Description
20.01.01	**7912AD/4041 Instrument Utility Software.** Subprograms that can be integrated into user-written programs with minimal modification, or serve as building blocks for developing test and measurement programs.
20.02.02	**7612D/4041 Instrument Utility Software.** Subprograms that can be integrated into user-written programs with minimal modification, or serve as building blocks for developing test and measurement programs.
20.06.05	**7D20/4041 Measurement Utilities.** Subprogram that performs a variety of common 7D20 waveform measurements. Designed to be integrated into user-written programs.
20.06.09	**7D20/4041 Waveform Analysis, V4.1.** Comprehensive waveform analysis software with menu selections for easy operation.
20.06.10	**7D20/4041 Auto Scale Routine.** Routine that performs autoscaling functions.
20.06.12	**7D20/4041 Limit Test Routine II.** Compares test waveforms against previously-stored reference waveforms.
20.06.13	**7D20/4041 Fast Data Logger, V1.1.** Records captured waveforms to a pre-formatted tape with 32 files.
20.06.14	**7D20/4041 Instrument Utility Software.** Subprograms that can be integrated into user-written programs with minimal modification, or serve as building blocks for developing test and measurement programs.
20.07.05	**390AD/4041 Instrument Utility Software.** Subprograms that can be integrated into user-written programs with minimal modification, or serve as building blocks for developing test and measurement programs.
20.10.08	**MI 5010 + 50M50/4041 A/D Conversion and Data Storage.** Permits up to 32,000 A-to-D conversions from the 50M10 to be output as a continuous string.
20.10.10	**TM 5000/4041 Instrument Utility Software.** Subprograms that can be integrated into user-written programs with minimal modification, or serve as a building block for developing test and measurement programs.
20.10.11	**TM 5000/4041 Test Program Generator — 4105 Version.** Provides easy set-up for tests using TM 5000 equipment under program control; menu-oriented for quick development.
20.10.12	**TM 5000/4041 Test Program Generator — ANSI Terminal Version.** ANSI terminal version of 20.10.11.
20.11.02	**CG 5001/4041 Oscilloscope Calibrator, V2.0.** Checks all major areas of oscilloscope accuracy against "Go, No/Go" criteria. Spec writer routine included for interactive creation of specification files for any particular oscilloscope.
20.12.05	**2465CTS/4041 Automatic and Semiautomatic Measurements.** Routines to perform many basic 2445/2465 functions.
20.13.01	**2430/4041 Waveform Analysis.** Comprehensive waveform analysis software with menu selections for easy operation.
20.13.02	**2430/4041 Instrument Utility Software.** Subprograms that can be integrated into user-written programs with minimal modification, or serve as building blocks for developing test and measurement programs.
20.20.08	**4041 Time Domain Analysis Routines, V3.0.** A set of time-domain measurement routines for Tek digitizers.
20.90.17	**4105/4041 EZ Draw, V3.8.** Menu-driven creation of graphic drawings and multi-sized text on the 4105.
20.90.18	**4105/4041 General Utilities.** A set of utilities for the 4041 System Controller. Includes file handlers, text editor, remark stripper, etc.

How To Order Programs

Instrumentation Software Library programs can be ordered via toll-free number from the Tektronix National Marketing Center:

1-800-426-2200, Extension 440

NOTE: This number is for ordering software only. For applications assistance, contact your local Tektronix Field Office and ask for the Instruments Group Application Engineer.

Software can also be ordered directly from your local Tektronix Field Office or representative. When ordering software, provide the following information:

DESCRIPTION: S49 Z101 Instrumentation Software
CATALOG NUMBER: (From above description or from catalog)
YOUR NAME:
YOUR MAILING ADDRESS:
METHOD OF PAYMENT:

Whenever possible, orders will be shipped within three working days of receipt.

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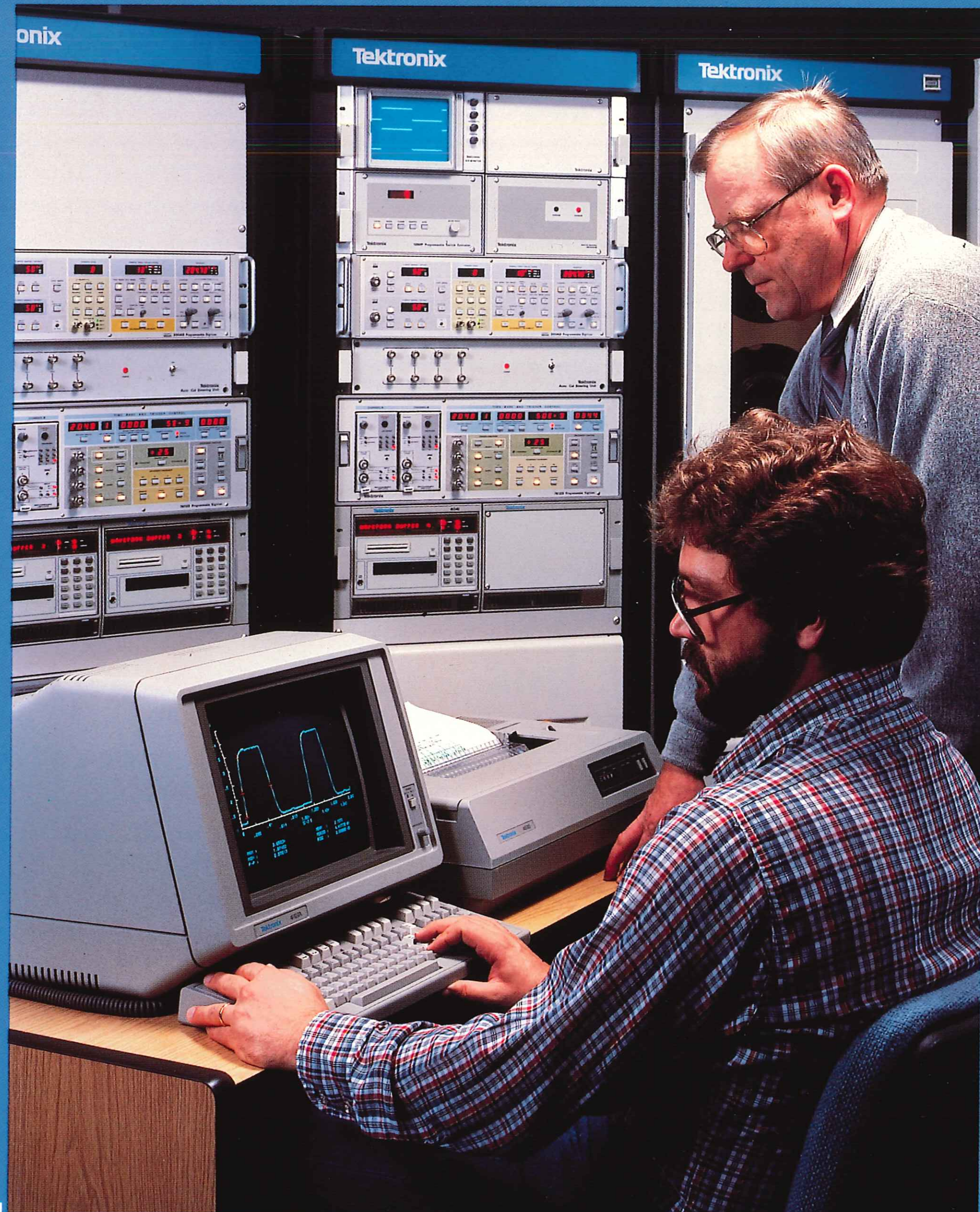

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TekMAP 7854/HP Series 200 software

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Revisiting the bus

"Instrumentation that can be operated via the IEEE 488 bus ranges from simple switches and power supplies to advanced, highly complex network analyzers and waveform digitizers — all controllable from a computer having the proper interface." The quote is from "Many Choices Complicate IEEE-488 Instrument Selection", an article first published in the March 1, 1985 issue of ELECTRONIC PRODUCTS.

The quote and the title indicate the scope of the article. It first describes talkers and listeners, then command languages, personal computers, software availability, and finally hardware considerations and memory size.

If this article sounds interesting — either as a review or as an introduction to the GPIB bus — reprints are available from Tektronix. You can get a copy by checking 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.

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