Vol. 3 No. 1 FALL 1977

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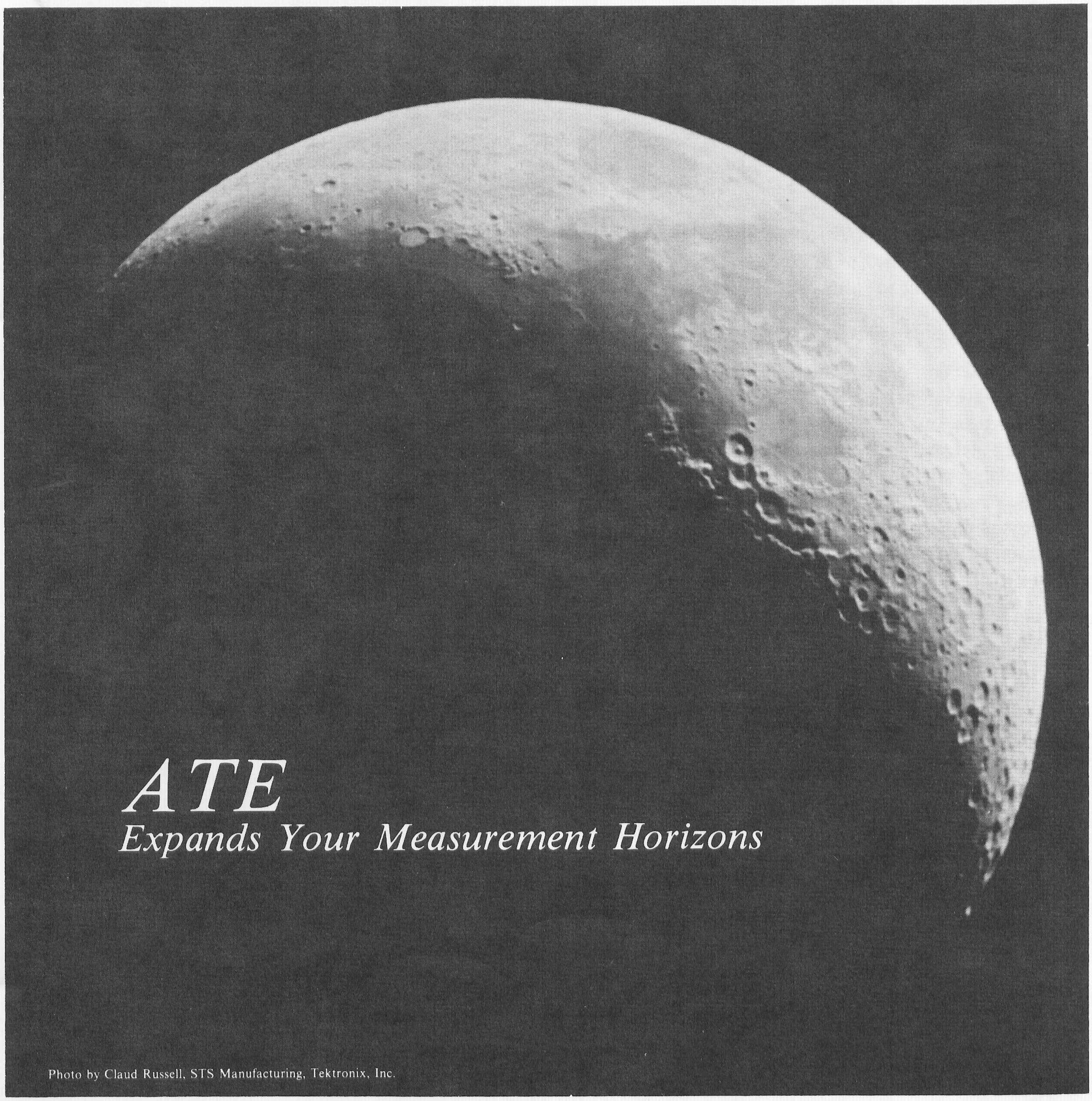
HANDSHAKE

Newsletter of the Signal Processing Systems Users Group

INSIDE:

Are you at the interfacing crossroads? Watch future issues of HANDSHAKE for new directions.



ATE
Expands Your Measurement Horizons

Photo by Claud Russell, STS Manufacturing, Tektronix, Inc.

Automatic Test Equipment: A Measure of the Future

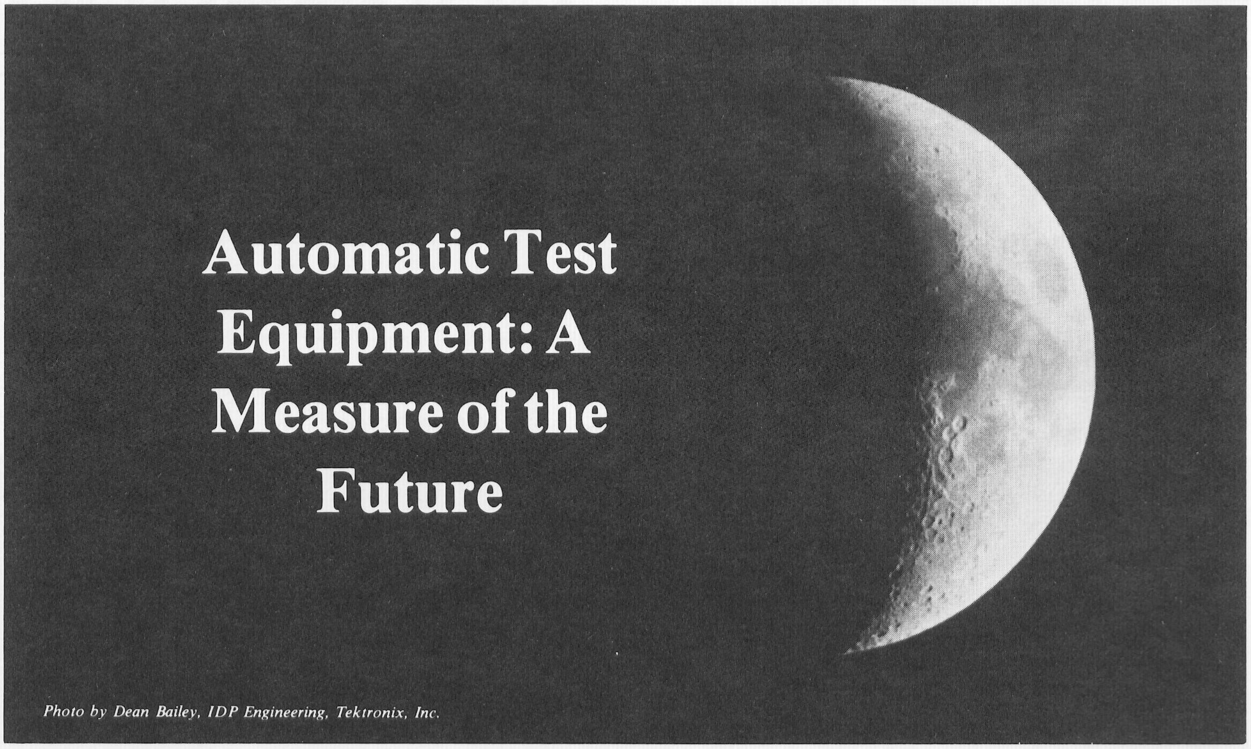


Photo by Dean Bailey, IDP Engineering, Tektronix, Inc.

"We live in a time when automation is ushering in a second industrial revolution."

Those are the words of Adlai E. Stevenson—perceptive for the time when they were spoken, and never truer than today. With rising production costs eroding profit margins, there is little choice but to automate. So, whole processes have become automated—not because people can't do the jobs, but because it is more economical to reserve people for the things that really have to be done by people.

In recent years, and increasingly so today, we are also faced with many tasks that cannot conceivably be performed by people. These are the tasks that must be done in remote locations, in hostile environments, or that are so complex or great in magnitude that the logistics of their accomplishment require automated techniques and equipment.

Reaching for the Moon

The space effort is probably the greatest example of modern automation. Although some may question the economics, the technological achievement is magnificent in scope.

The moon provided a learning, testing, and proving ground for many automation concepts and techniques. Navigation systems, life support systems, surface exploration instruments, and systems for monitoring systems were all automated. But still, astronauts were there to "tweak" wandering equipment back to the job. The more recent exploration of Mars was a different story, though. The journey was too long for human passengers. Virtually everything had to be done automatically, with the only human touch being through earthbound video monitors and telemetry links.

Of course, before anything left the earth, its operation was checked thoroughly. However, the checkout procedures for many systems were too exhaustive, too time consuming, and too demanding to be carried out manually. So automatic test systems were designed and built, many of which were computer controlled and driven by specialized software.

The same tack was taken by the military. As early as the mid-1950s, avionics and missiles were becoming too complex for maintenance by the typical technician.[1] Also, system designs were changing too fast for documentation and training to be kept current. As a result, the concept of general purpose, automatic test equipment (ATE) emerged.

Industry was not far behind either. After watching the successes and shortcomings of the aerospace and military projects, manufacturers began building their own ATE systems. These imitated the successes and generally avoided the mistakes of previous government-funded systems. The reward was that ATE systems proved to be ideal quality control tools, particularly where large quantities of similar devices were being produced or where 100% testing had to be done. The chief advantages were, and still are, rapid throughput and high repeatability with substantially reduced measurement error.

Some Problems Along the Way

Not everything was A-Okay with industry's entry into ATE, though. Primarily, each system tended to be specialized for a particular application. Most automated instrumentation was not off the shelf. Instruments were either specially designed for the task or were modified versions of off-the-shelf instruments. Then there were the interfaces and software. These proliferated with very little standardization, resulting in systems that were impervious to modifications for handling new product lines or new test procedures.

There was the cost, too. Designing specialized, automated test systems from the ground up doesn't come cheap!

In some cases, initial cost was saved by interfacing standard instrumentation to the system. But then the system was only semiautomatic, still requiring some knob turning and button pushing from human operators. The inherent fallibility of manual operation shone through, and the rewards were semiautomatic systems that improved the throughput of wrong answers.

Naturally, instrument manufacturers followed the ATE problem with interest. Some programmable features were added to general-purpose instruments, but for the most part, fully programmable, off-the-shelf instruments remained the ATE system designer's pipe dream until the advent of integrated circuits. This was a shot in the arm, but the real break came with the more recent development of microprocessors. Computers on a chip made programmable, general-purpose instrumentation a reality.

However, with their entry into the ATE business, instrument manufacturers also entered into the compatibility guessing game. "If we are going to make this thing programmable, what computer are we going to make it compatible with?" became the question of the day.

Answers in Standardization

One answer came from Europe. In 1969, the European Standards on Nuclear Electronics developed the CAMAC (Computer-Automated Measurement and Control) standard for use in nuclear laboratories.[2] The CAMAC standard was later adopted as IEEE (Institute of Electrical and Electronic Engineers) Standard 583-1975.

The CAMAC standard specifies a data bus as well as the physical dimensions of a "crate." The CAMAC crate holds 24 modules for interfacing test instruments, sensors, and other devices to a computer.

There is also a 25th position in the crate for a crate controller which may also contain a computer interface (see Fig. 1 for the typical CAMAC configurations).

Although the CAMAC concept was directed toward the nuclear field, its high data density and transfer rate—as well as its ability to tie many CAMAC compatible instruments into one system—gained it acceptance in such diverse fields as process control and astronomy.

CAMAC was not the best answer for many people, though. The military has its own needs, so it has continued with its own unique programs. Some instrument manufacturers balked at the physical specifications placed on them by CAMAC. The biggest objection, however, came from ATE users and designers. "Why pay for a 25-module CAMAC crate when all I want to do is hook two instruments together?" was a common reply to CAMAC proponents.

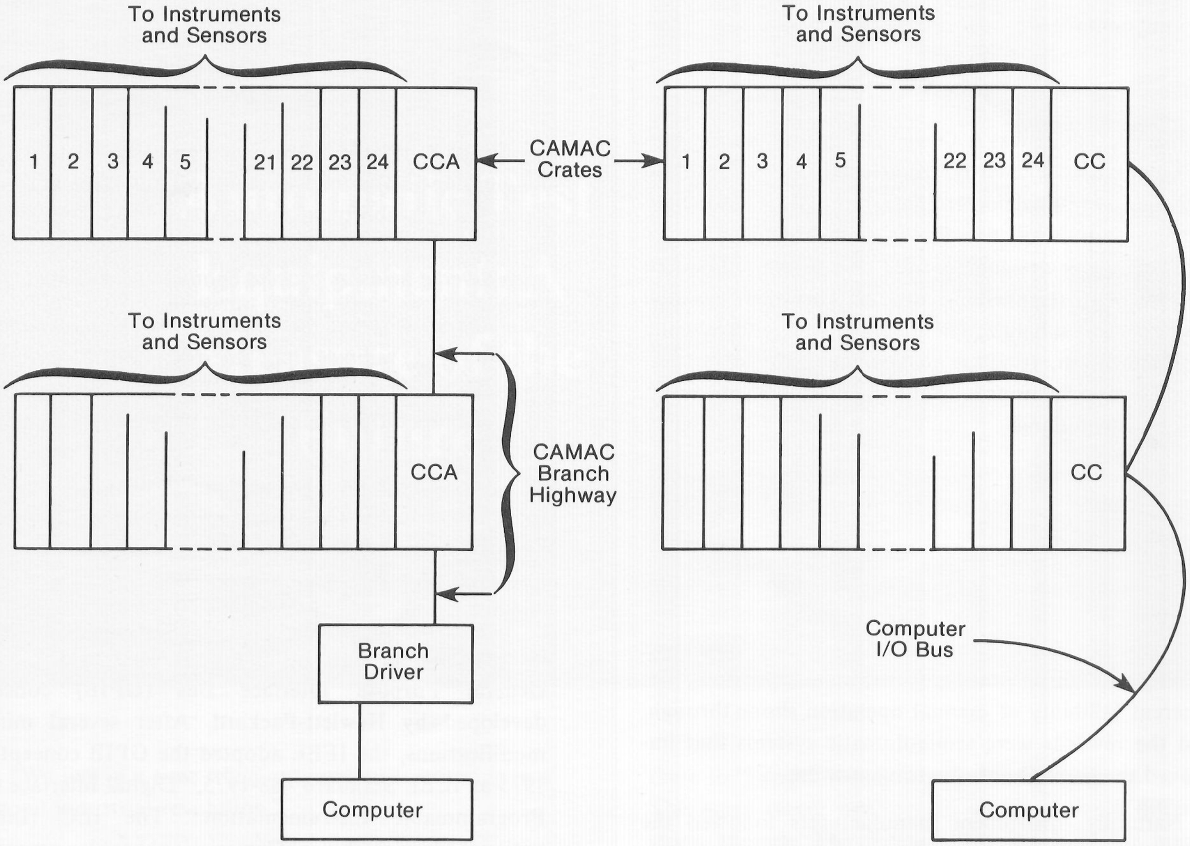
In answer, another standard began to emerge. In 1972, international standardization groups began to look at the General Purpose Interface Bus (GPIB) concept developed by Hewlett-Packard. After several minor modifications, the IEEE adopted the GPIB concept in 1975 as IEEE Standard 488-1975, "Digital Interface for Programmable Instrumentation." The IEC (International Electrotechnical Commission) has also prepared a standards document based on the GPIB which is due for publication this year.

IEEE 488 is flexible in different ways than CAMAC. Other than a standard connector, it doesn't specify the physical shape or size of equipment. An IEEE 488 compatible instrument doesn't have to interface to a crate; it simply plugs into a bus arrangement in the manner indicated in Fig. 2. Also, it is small-system oriented, with a maximum of 15 device loads allowed on the IEEE 488 bus. (There is a primary address for each device load. Secondary addressing, however, allows several instruments to be assigned to each primary address. The concept is similar to apartment house addressing, where a primary street address refers to the building and secondary addresses refer to each apartment.)

IEEE 488 specifies the minimum requirements for getting different instruments together. These are 1.) a standard plug with 16 specified signal lines, 2.) voltage and current limits at the plug, and 3.) timing and message protocol for control and data transfer between instruments and the controller. Anything beyond this gets into the realm of device-dependent operation, and the aim of IEEE 488 is to remain device independent. So, beyond communication and data transfer, you are free to program instrument functions in any manner.[3 and 4]

continued on page 4

ATE continued from page 3



a. CAMAC branch highway configuration uses Type A Crate Controllers (CCA).

b. The Crate Controllers (CC) in the second type of configuration contain computer interface.

Fig. 1. There are two main configurations used under CAMAC, the first internationally recognized standard for ATE systems.

Now the Stars Are the Limit

With the IEEE 488 for standardization and microprocessors for programmability, truly automatic test equipment can be made available. A good example is the recently developed TEKTRONIX 7912AD Programmable Digitizer along with the 7A16P Programmable Amplifier plug-in and the 7B90P Programmable Time Base plug-in.

Although the 7912AD with its plug-ins and their push buttons looks like a standard manual instrument, it is not. It is fully programmable. Hook it up to a TEKTRONIX IEEE 488 compatible controller, add TEK SPS BASIC software, and you have a programmable ATE system with full signal processing capabilities. You can push the time base and amplifier buttons to set up the 7912AD for data acquisition and let software "learn" the settings for future acquisitions, or you can control the settings entirely through software.

Also, the biggest problem with the IEEE 488—writing device-dependent software for individual instruments—is circumvented. In addition to an IEEE 488 Driver, TEK SPS BASIC will include an instrument driver module for handling the 7912AD and its programmable plug-ins. And, as other programmable instruments are developed at Tektronix, instrument driver modules will be made available for addition to existing TEK SPS BASIC software packages.

"Fine," you say. "But what about my signal generator? And I just bought a new counter. I plan to include them in my ATE system."

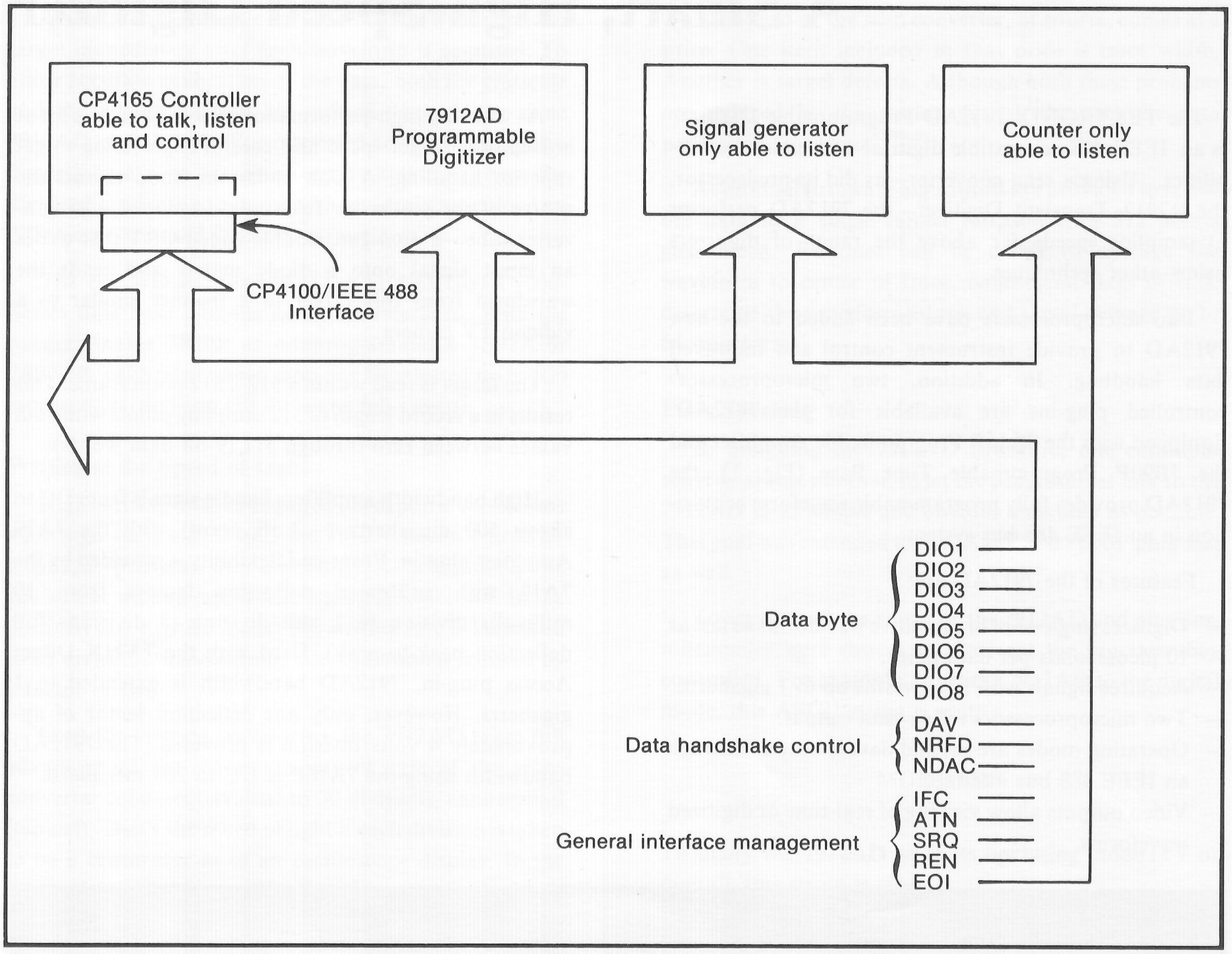


Fig. 2. A typical IEEE 488 system showing bus organization.

Great! As long as your other instruments are IEEE 488 compatible TEK SPS BASIC can handle them. You won't have to modify software because TEK SPS BASIC is modular. It lets you write and "plug in" your own special drivers and nonresident commands without having to change the main body of software. And, to help you do this, both high-level and assembly-level language support packages are available with TEK SPS BASIC software.

Now, all you have to do is sit back and watch your test equipment make measurements—automatically!!

By Bob Ramirez, HANDSHAKE Staff.

[1] *Liquori, F., Editor,* ***Automatic Test Equipment: Hardware, Software, and Management,*** *IEEE Press, 1974.*

[2] *Horelick, D., and R.S. Larsen, "CAMAC: A Modular Standard,"* ***IEEE Spectrum,*** *April 1976.*

[3] *Conway, J., "What You Should Know About the 488 and 583 Interface Standards,"* ***EDN,*** *August 5, 1976.*

[4] *IEEE Std. 488-1975,* ***IEEE Standard Digital Interface for Programmable Instrumentation,*** *The Institute of Electrical and Electronics Engineers, Inc., 1975.*

The Programmable 7912AD— A Smart, High-Speed Digitizer

The TEKTRONIX 7912AD Programmable Digitizer is an IEEE 488 compatible digitizer with unique capabilities. Using a scan converter—as did its predecessor, the R7912 Transient Digitizer—the 7912AD performs at sampling speeds far above the range of digitizers using other techniques.

Two microprocessers have been added to the new 7912AD to provide instrument control and improved data handling. In addition, two microprocessor-controlled plug-ins are available for the 7912AD. Equipped with the 7A16P Programmable Amplifier and the 7B90P Programmable Time Base (Fig. 1), the 7912AD provides fully programmable waveform acquisition in an IEEE 488 bus system.

Features of the 7912AD are:

- Digitizes single-shot or repetitive waveforms as fast as 10 picoseconds per data point.
- Acquires signals with bandwidths up to 1 gigahertz.
- Two microprocessors refine data output.
- Operating modes are set and data is output through an IEEE 488 bus interface.
- Video outputs allow viewing of real-time or digitized waveforms.

As with any high-performance vehicle, it takes a lot of horsepower to get speed and careful engineering to get superior handling. A look under the hood reveals the source of the power—a Tektronix-developed scan converter tube—a dual-gun, double-ended CRT that writes an input signal onto a diode matrix and reads the waveform from this target in a manner similar to a vidicon TV camera.

The target is read within a 512 x 512 point frame. This results in a record length of 512 sampling points with data values between zero through 511 (9-bit data words).

High bandwidth amplifiers handle signals from DC to above 500 megahertz (—3 dB point) with the 7A19 Amplifier plug-in. Front-end flexibility is provided by the 7A19 with calibrated deflection factors from 10 millivolts/division to 1 volt/division (8 divisions full deflection peak-to-peak). Used with the 7A21N Direct Access plug-in, 7912AD bandwidth is extended to 1 gigahertz. However, only one deflection factor of approximately 4 volts/division is provided. The 7912AD bandwidth using the 7A16P is DC to 200 megahertz.

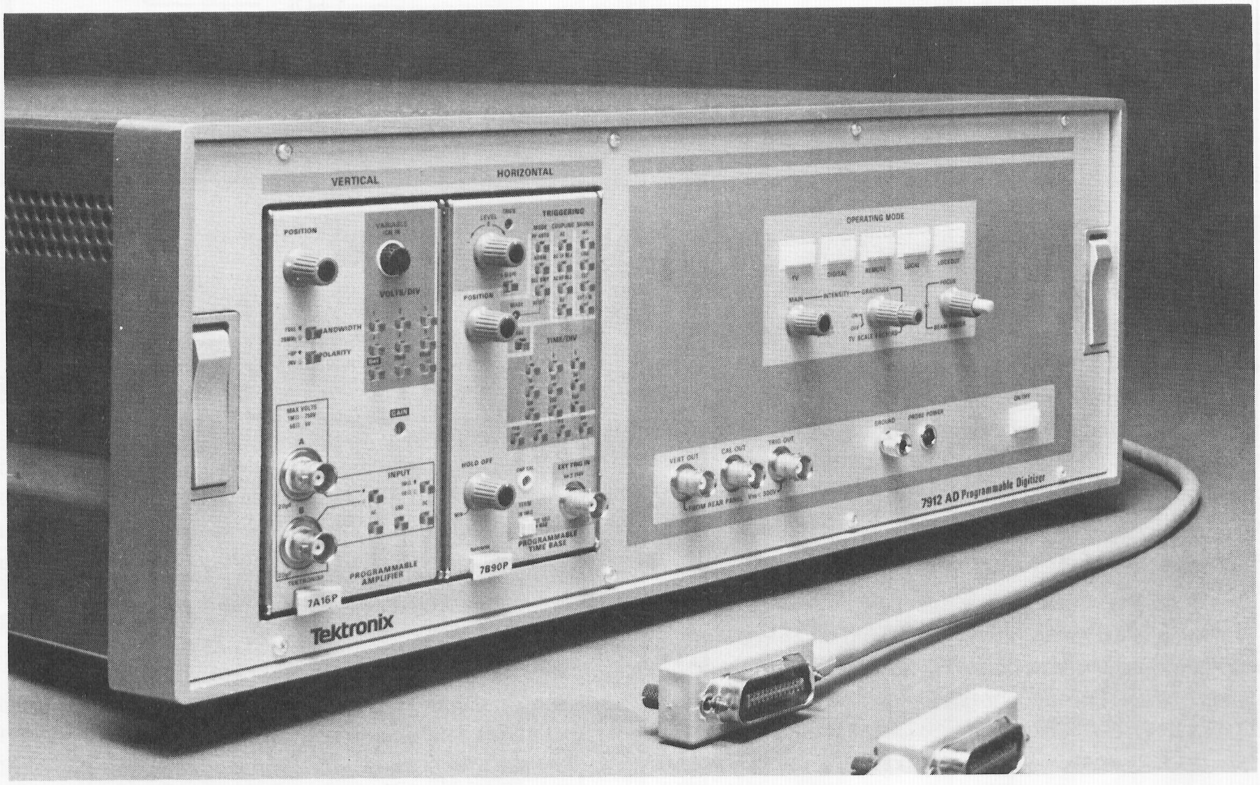


Fig. 1. The 7912AD Programmable Digitizer, the 7A16P Programmable Amplifier, and the 7B90P Programmable Time Base make a fully programmable digitizer package that includes an IEEE 488 bus interface.

An electronic graticule is automatically written on the target immediately after each waveform is acquired. To allow accurate calibration of the data, both the graticule and the acquired signal are written through the same 7912AD signal path. For increased accuracy, geometry distortions can be processed out by looking at how the digitized graticule compares with an ideal graticule. Any differences are used for data corrections.

The 7912AD accepts any of the TEKTRONIX 7000-Series time base plug-ins as a time reference. With the programmable 7B90P or nonprogrammable 7B92A or 7B80GB, calibrated sweep rates can be selected up to 500 picoseconds/division (10 divisions full sweep).

Writing at the Speed of Light

High writing rate is required to capture waveforms with high bandwidths and the 7912AD scan converter technique provides this capability. As a digitizer, the equivalent writing rate is 8 divisions/nanosecond. In the optional fast-digitize mode, the writing rate is increased to 20 divisions/nanosecond, but resolution is reduced by a factor of two.

Used for viewing waveforms, the 7912AD takes full advantage of the maximum writing rate of the scan-converter tube—equavalent to 30 divisions/nanosecond (typical). That's the speed of light if each division is taken to be a centimeter as in an oscilloscope display. In the optional fast-digitize mode, the writing rate is doubled.

Although the scan-converter writing beam is only traveling at a fraction of the speed of light, the apparent writing rate of 30 divisions/nanosecond (60 divisions/nanosecond in fast digitize), is possible when the waveform is read from the small target and expanded for display on a monitor.

Although video outputs are provided to view waveforms as they are acquired or after they are digitized, it is as a data collector and number cruncher that the 7912AD really stars.

To store the data from the scan-converter tube and output it in a more usable format, the 7912AD uses the smarts of two microprocessors. One, a Motorola 6800, handles instrument control over the IEEE 488 bus. The other, an AMD 2900, supplies the bipolar speed to unscramble the data pouring in from the scan converter. Using algorithms in firmware, these two microprocessors team up to output the data starting with time zero in the sampling window, to output the graticule and scale factors, and to flag target defects. This internal data crunching relieves an external processor of a great deal of routine data handling and speeds up acquisition time (16 milliseconds per waveform, 5 milliseconds per waveform in fast-digitize).

The speed of the scan converter, of course, comes at a price. One item included in that price is trace width. Another is target defects. Although both these probems are reduced by the analog design, they require data processing to correct.

Additional firmware algorithms are provided to refine the data to a single-valued function with 512 points guaranteed. Routines can be called to average the waveform to center of trace, collect and flags defects, determine the waveform edges, and signal average up to 64 waveforms.

Plain Speaking

In designing the 7912AD firmware, one common-sense goal was put first: to let the programmer talk to the 7912AD in as simple and obvious a manner as possible. This goal was extended to the 7A16P and 7B90P plug-ins, as well.

To set or read the status of the 7912AD and plug-ins, mnemonics were chosen to represent the function they controlled. For example, to set the 7912AD to the digital mode, this ASCII string is sent:

```
MODE DIG
```

To query the 7912AD as to its operating mode (TV or digital), this string is sent:

```
MODE?
```

Design of the firmware is fully consistent with the handshakes and protocols set forth in IEEE Standard 488-1975. Extended addresses are used so that the 7912AD and its plug-ins (if programmable) appear as separate devices on the bus, but provide only one electrical load on the bus. The 7912AD acts as a transparent interface between the plug-ins and the IEEE 488 bus. To prevent front-panel access, operator controls of both the 7912AD and the plug-ins can be locked out under program command.

With IEEE 488 bus compatibility and programmable plug-ins, the 7912AD combines very fast digitizing with programmability. This combination makes possible widespread application in automatic test equipment (ATE) systems by virtue of its standard data connector, timing and transfer protocols, and ease of programming.

By Jim Kimball, HANDSHAKE staff.

Getting the Most out of TEK BASIC GRAPHICS

Autoscaled X-Y Plots

Are you interested in such things as Nyquist plots, hysteresis data, mechanical stress vs. strain? If so, then you need to be able to make X-Y plots. A program for doing just that has been contributed to HANDSHAKE by Randall O. Decker of United Technologies Research Center. A listing of this TEK SPS BASIC routine is given in Fig. 1.

There are three variables that must be defined before the program can be run. These are S, the number of points to be plotted; FE, the array of data for the vertical axis; and W, the array of data for the horizontal axis.

For example, let's say you are testing core materials for inductors and need some hysteresis plots. You might have a test setup like that shown in Fig. 2. A field-force waveform, developed across precision resistor R_s, would be acquired and stored in array W. Simultaneously, a waveform related to flux would be acquired from the secondary windings and stored in array FE. Assuming that FE and W are dimensioned to 511 and you want to plot all points (0 through 511), S would be set to 511.

```
1000 XN=5\YN=5
1010 JX=5\NX=3
1015 JY=5\NY=3
1020 LE=120
1030 RE=985
1040 BO=100
1050 TP=720
1060 REM THIS PROGRAM WILL GRAPH X VS Y
1070 REM
1080 REM S DETERMINES # POINTS PLOTTED
1090 REM
1100 PAGE
1110 DELETE X
1120 X=FE\REM FE IS THE ARRAY FOR THE VERT AXIS
1130 GOSUB 1310
1140 YL=XL\YH=XH\YJ=XJ
1150 DELETE Y
1160 Y=FE
1170 DELETE X\X=W\REM W IS THE ARRAY FOR THE HORIZ AXIS
1180 GOSUB 1310
1190 VIEWPORT LE,RE,BO,TP
1200 WINDOW XL,XH,YL,YH
1210 SETGR VIEW,GRAT JX,JY,NX,NY,NOPLOT,TICS XJ,YJ,XN,YN,WINDOW
1220 GRAPH X
1230 MOVE X(0),Y(0)
1240 FOR I=1 TO S
1250 DRAW X(I),Y(I)
1260 NEXT I
1270 RESETG
1280 PRINT "YOUR MESSAGE HERE"
1290 END
1300 REM ROUTINE TO SET SCALE
1310 G=1
1320 H=1
1330 TS=MAX(X(0:S))-MIN(X(0:S))
1340 IF TS<10 THEN GOTO 1420
1350 REM TS NOW>=10
1360 IF TS>100 THEN GOTO 1450
1370 REM 10<=TS<=100
1380 XL=(ITP(MIN(X(0:S))*G*H*.2)-1)/(G*H*.2)\REM 2 TO 20
1390 XH=(ITP(MAX(X(0:S))*G*H*.2)+1)/(G*H*.2)\REM 2 TO 20
1400 XJ=(XH-XL)*G*H*.2\REM #MAJOR LINES
1410 RETURN
1420 TS=10*TS
1430 G=10*G
1440 GOTO 1340
1450 TS=TS/10
1460 H=H/10
1470 GOTO 1360
```

Fig. 1. Listing of X-Y Plot Routine in TEK SPS BASIC.

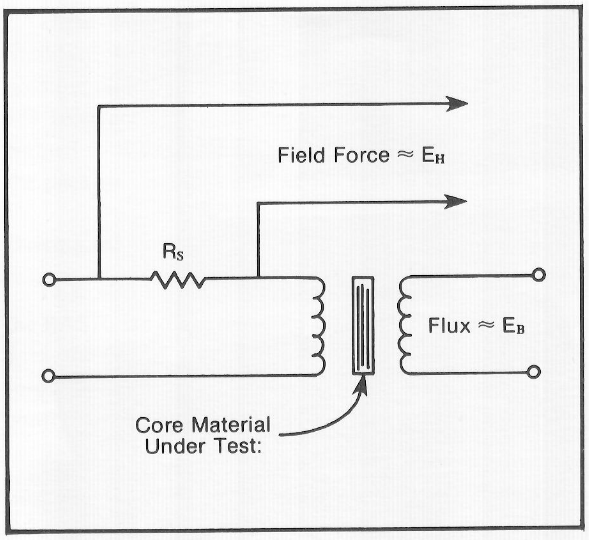
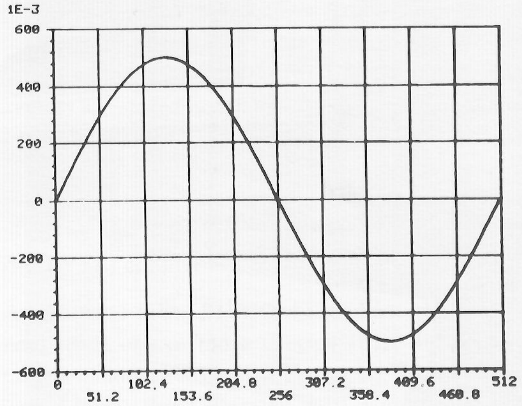


Fig. 2. Evaluating magnetic materials is one of many examples where X-Y plotting (in this case, E_B vs. E_H) can add a wealth of information to the test results.

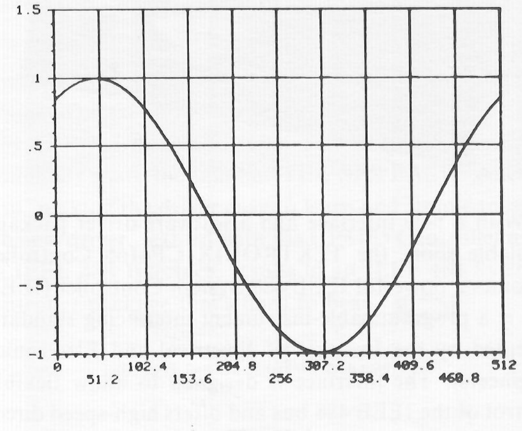
The X-Y Plot Routine starts at line 1000 by initializing various graphics variables. Then the X and Y plot arrays are set up and scales selected in the subroutine covered by lines 1300 through 1470. Final return from the subroutine goes to line 1190. Lines 1190 through 1290 constitute the remainder of the program and handle the graphics. More specifically, lines 1190, 1200, and 1210 set up the graphics viewport, window, and graticule. Line 1220 causes a scaled graticule to be graphed on the terminal screen, and line 1230 sets up software for plotting the first data point. The rest of the data points are plotted with the DRAW command and FOR loop in lines 1240, 1250, and 1260. When the plot is completed, 1270 resets the graphics software to its default condition without altering what is already on the terminal screen. The PRINT statement at line 1280 allows you to enter a message describing or labeling your X-Y plot. Line 1290 ENDS the program.

Fig. 3c is an example of the output from the X-Y Plot Routine. It is a cross plot of the sinusoids in Figs. 3a and b, which could be single-cycle stress and strain data from a fatigue test, for example. The resulting X-Y plot would then be used to determine such mechanical data as specimen damping (area contained by the loop) and specific specimen damping (ratio of contained area to area under the loop). For other fields of study, other interpretations of the X-Y plot are, of course, necessary.

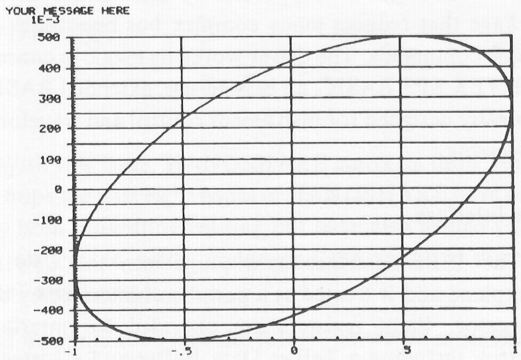
By Bob Ramirez, HANDSHAKE Staff.
Based on a program contributed by
Randall O. Decker of United Technologies
Research Center, East Hartford, CT.



a. The Y data.



b. The X data.



c. X-Y plot of the data in a and b.

Fig. 3. The X-Y Plot Routine plots the Y data on the vertical and the X data on the horizontal. In the above example, the data in a and b could represent single-cycle stress and strain data from a fatigue test. The X-Y plot in c would then represent material hysteresis.

CP4165 Goes IEEE 488

With a new interface and a software driver package available soon, the TEKTRONIX CP4165 Controller becomes a powerful IEEE 488 System Controller (IEEE 488 is a programmable-instrument interfacing standard accepted by the Institute of Electrical and Electronics Engineers). The interface is designed to allow flexible control of the IEEE 488 bus and offers high-speed direct memory access (DMA) capability as well.

The hardware is supported by a software driver package that reduces many complex bus operations to simple commands. The driver works its magic in concert with TEK SPS BASIC, an easy-to-use, extended BASIC expressly designed for instrument control and waveform processing.

The Interface

The IEEE interface card plugs into the CP4165 backplane and is treated as a peripheral interface by the processor. Eight registers are provided for interface control, including a Talker Data Buffer and a Listener Data Buffer for non-DMA data transfers, as well as a Data Count Register and a Bus Address Register to control DMA transfers. Bus Status and Bus Control registers allow the processor to monitor and control the IEEE 488 interface lines. Interface Status and Interrupt Control registers provide improved control of acquisition instruments.

Direct Memory Access allows large amounts of data to be tranferred over the IEEE bus at high speed. The data can be transferred in two modes, hog or non-hog. Hog mode is the fastest, forcing the CP4165 to send or receive data in large blocks. The data transfer is interrupted only by the refresh needs of the CP4165 dynamic memory. Non-hog DMA transfers aren't quite as fast because the controller data bus is released after each byte transfer.

The CP4165/IEEE 488 Interface supports the following functional subsets listed in Appendix C of the IEEE 488 standard:

SH1	Complete Source Handshake capability
AH1	Complete Acceptor Handshake capability
TE5	Extended Address Talker function
LE3	Extended Address Listener function
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No response to Parallel Poll (can conduct a Parallel Poll, however)
DC1	Device Clear capability
DT1	Device Trigger capability

The interface also performs the Controller Interface functions as follows:

C1	System Controller
C2	Send IFC and Take Charge
C3	Send REN
C4	Respond to SRQ
C5	Send Interface Messages, Receive Control, Pass Control, Pass Control to Self, Conduct Parallel Poll, Take Control Synchronously

These capabilities are fully described in the IEEE Standard 488-1975. They include nearly all functions possible under the standard, making the CP4165/IEEE 488 Interface one of the most versatile available. When teamed with a special TEK SPS BASIC software driver, the package becomes a powerful system controller.

Driving the Bus

TEK SPS BASIC is a high-level, extended version of the BASIC language designed for instrument control and data processing. Its versatile control structure and easy-to-use command set make it a natural for IEEE 488 bus control.

To make bus control as simple and efficient as possible, a special IEEE 488 driver is included in TEK SPS BASIC. The driver uses familiar commands and understandable mnemonics to simplify complex bus operations for the programmer. The PUT command, for example, automatically sets Remote Enable, sends one or more listen addresses supplied by the command arguments and a string of data (any format), then terminates with the UNListen command. All done for you by the driver. A GET command does the reverse—sends a talk address and waits for data. It accepts data until a specified quantity is received or until an EOI (End Or Identify) message occurs. All commands are time-out protected to prevent "hanging" the bus. The time-out period is adjustable, and is set by the SIFTO (Set InterFace Time-Out) command.

The DMA capabilities of the CP4165/IEEE 488 Interface are enhanced by the driver to allow handling of a wide variety of data formats. DMA data can be received in PAK mode, where characters received are stored in contiguous memory locations, or UNPak mode, where characters are stored in the low byte of contiguous word locations. DMA data consisting of two bytes per data word can be stored High- or Low-Byte-First with the HBF and LBF commands. Single-byte transfers are handled by the RBYTE (Read BYTE) and WBYTE (Write BYTE) commands.

A command called SIFCOM (Send InterFace COMmands) sends one or more selected IEEE 488 interface messages, including GTL (Go To Local), SDC (Selected Device Clear), PPC (Parallel Poll Configure), GET (Group Execute Trigger; not to be confused with the software GET command described earlier), LLO (Local LockOut), DCL (Device CLear), and PPU (Parallel Poll Unconfigure).

A host of other commands are included, so you can program the controller to accept interrupts (the WHEN command), test status, perform serial polls or parallel polls (PPOLL), check error status, and more. All commands share the familiar TEK SPS BASIC general form, making the driver easy to learn and simple to use. The new driver, teamed with the CP4165 Controller and the IEEE 488 Interface, results in an IEEE 488 System Controller package that's hard to beat.

By Larry Larison, HANDSHAKE staff.

Two Years and Growing!

With this issue, HANDSHAKE starts its third year. We hope the past eight issues of HANDSHAKE have not only been interesting reading but have also helped you, our readers, to better understand the world of digital signal processing.

If we could look into the future, we would more than likely be amazed at the advancements yet to be made in the area of signal processing. But it's probably fortunate that we can't see all of these changes at once as we would no doubt be overwhelmed by it all. (To gain a perspective, think back over the changes you've seen within the past five years!) However, as each advancement is made, HANDSHAKE will continue to inform you of these new signal-processing techniques.

The Editor

Literature Available from Tektronix

In this issue of HANDSHAKE, we are providing a full listing of Tektronix literature on Signal Processing Systems. To get copies of any of these publications, check the appropriate box on the HANDSHAKE reply card.

1. Measuring Transistor Switching Times with the DPO—AX-3481

Transistor turn-on, turn-off, delay, and storage times cannot be specified exactly. Precise data can only be obtained by measurements on individual switching transistors. This application note tells how to acquire switching waveforms and lists a DPO and WDI TEK BASIC program for computing switching times.

2. TDR Difference Testing with Tektronix Signal Processing Systems—AX-3482

This application note explains difference testing and shows how it can be used along with Time-Domain Reflectometer (TDR) techniques to perform comparative evaluations of terminators, connectors, and other passive devices. A flow diagram for a difference testing program is included.

3. Automatic Measurement of Nodular Iron Cast Parts—AX-3506

Making nodular iron is tricky. To be sure it is right, 100 percent testing of cast parts is necessary. This application note describes an automated system that uses ultrasonics to test nodularity in cast parts.

4. Windowing to Control FFT Leakage—AX-3336

Windowing is a technique used to control the leakage that may occur when the fast Fourier transform (FFT) is used to transform waveforms to the frequency domain. This application note describes leakage and the various window shapes that can be used to control it.

5. Mechanical Measurements Using the DPO—AX-3187

The DPO can be used to acquire and analyze transducer-generated data from rotating machinery tests. This application note describes some of the transducers available and some simple processing routines to aid in analyzing their output.

6. DPO Program Library Techniques—AX-3482

The task of programming can be simplified by using program libraries. This application note discusses techniques for building user-oriented program libraries and suggests methods of writing and using subroutines.

7. Engine Performance Measurements—AX-2937

The DPO, along with suitable transducers, can be used to automatically measure many of the parameters of an internal combustion engine. This application note describes the technique and provides a sample program.

8. A Solution to Pulsed Laser Measurement Problems—AX-2932

This application note discusses the measurement requirements of a basic pulsed laser system, presents measurement methods, and suggests solutions through the use of an R7912 Transient Digitizer.

9. Pulsed Laser Measurements Using the R7912 Transient Digitizer—AX-2983

This application note discusses the experimental portion of laser research and the possible roles of the R7912 in that research.

10. Automated Component Testing — It's a Reality...Thanks to Minicomputers

Microwave component testing can generate reams of data. Gathering that data and reducing it to a meaningful format are the problems considered in this article reprint from **Microwave Systems News**, June/July, 1976.

11. Storage Tube with Silicon Target Captures Very Fast Transients

The R7912 uses a unique scan converter with a highly sensitive silicon-diode-array target to acquire and store single-shot signals. This article—reprinted from **Electronics**, August 30, 1973—explains the concept and structure of the tube.

12. Characterizing the Laser

This article—reprinted from **Industrial Research**, July, 1974— describes how the R7912 Transient Digitizer can be used to determine the characteristics of a laser pulse train and to perform laser system alignment.

13. The Fast Fourier Transform's Errors are Predictable, Therefore Manageable

One's first brush with the fast Fourier transform (FFT) is often disconcerting because turning the classical Fourier transform into the FFT introduces errors. The major errors, leakage and aliasing, and methods for reducing their effects are discussed in this article reprint from **Electronics**, June 13, 1974.

14. Fast Fourier Transform Makes Correlation Simpler

One of the attractions of the fast Fourier transform (FFT) is that it simplifies implementation of correlation techniques. Thus, correlation becomes a general analysis tool. There are some pitfalls, however, and this article reprint from **Electronics** (June 26, 1976) points them out and discusses some ways around them.

15. FFT Wall Chart—AX-3352

This is a 34 x 44 inch wall chart which can be used either in the lab or the classroom. One side of the chart is devoted to classical Fourier analysis and establishes the foundation for the FFT. The other side is devoted to the FFT, the modern digital approach to frequency-domain analysis. The concepts of windowing and sampling are fully illustrated along with a section on important FFT properties. Also included is a discussion on improving FFT results—how to avoid aliasing and what to do about leakage.

Literature Catalog Available

If your interests run broader than Signal Processing Systems, you'll probably want to take a look at a new brochure entitled **Tektronix Listing of Free Publications**. In addition to the above listed literature, this brochure catalogs literature covering the whole spectrum of Tektronix products, from Automated Test Equipment to Oscilloscopes. Also included in the catalog is an order form for obtaining these free publications.

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We would also like to invite you to send in programs or programming techniques and hints that you have found helpful. Also of special interest are articles using the graphic capabilities of TEK SPS BASIC Software.

Address comments to:

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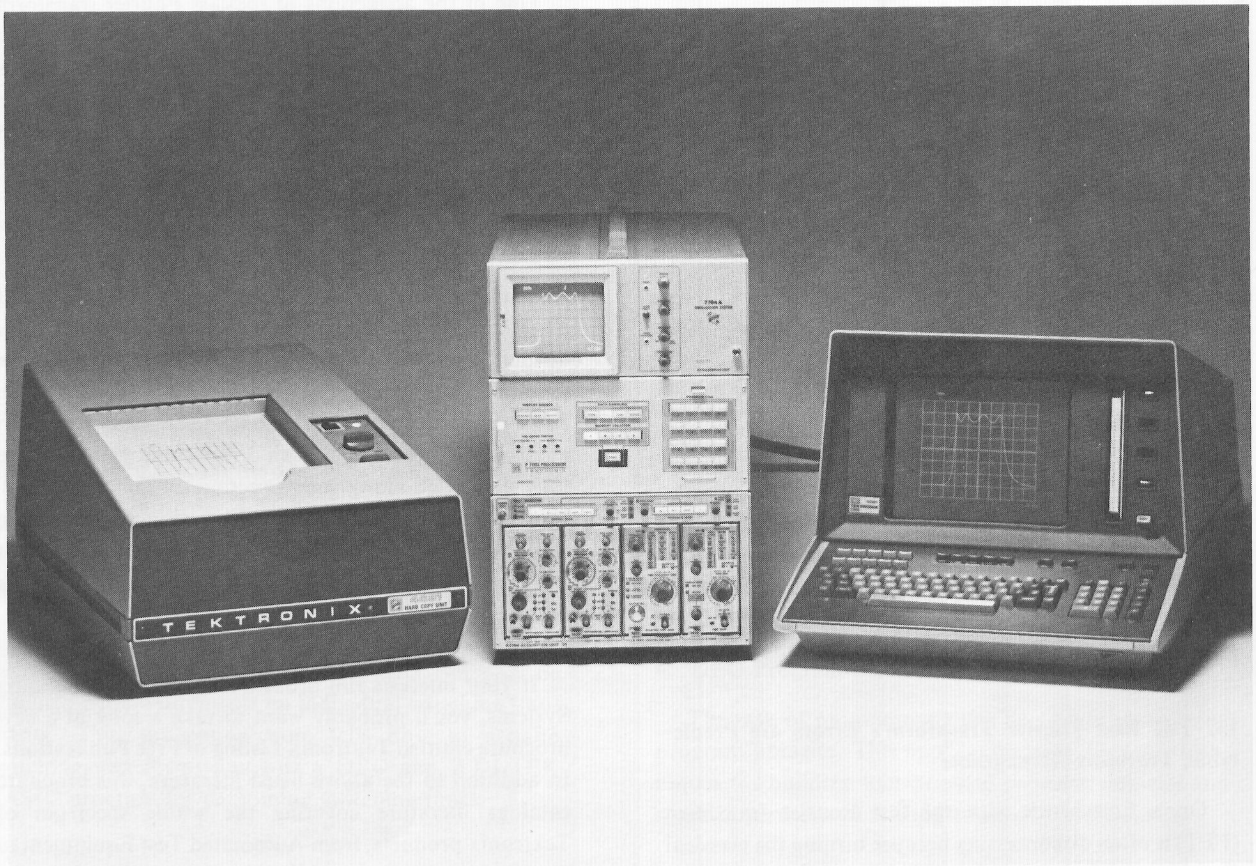
IEEE 488 Increases DPO Interfacing Possibilities



The TEKTRONIX Digital Processing Oscilloscope (DPO) has already proved itself as a general waveform processing instrument. Now, however, there is something new for the DPO—a special product that boosts its capabilities into the realm of ATE (Automatic Test Equipment) systems. This new product is the P7001/IEEE 488 Interface.

The P7001/IEEE 488 Interface conforms to IEEE Standard 488-1975, "IEEE Standard Digital Interface for Programmable Instrumentation," published in 1975 by the Institute of Electrical and Electronics Engineers (IEEE). This interface allows the DPO to be used with an IEEE 488 compatible controller, such as a TEKTRONIX 4051 Graphic System.

As an IEEE 488 device, the DPO can be a talker only or a listener only. When it is a talker, the DPO can send digitized waveforms, readout information, and its current device status to the system controller or other IEEE 488 device. As a listener, it can receive data and commands from the system controller or another IEEE 488 device.

Interfacing occurs within the P7001 Processor section of the DPO. The P7001/IEEE 488 Interface is a dual-card assembly that is installed in the interface slots of the P7001. All necessary power for the interface is taken from the P7001 Power Supply via the Main Interface Board. Thus, converting the DPO to IEEE 488 hardware compatibility consists of little more than putting a card into a slot and throwing a few switches to set a device address. With appropriate system-controller software, the DPO becomes fully compatible with other IEEE 488 instruments.*

Programming information is given in the P7001/IEEE 488 Interface Instruction Manual. Of particular interest are complete examples for using a TEKTRONIX 4051 Graphic System as the system controller for the DPO. The 4051 controller offers desk-top computational power, high-level BASIC with graphics, up to 32 kilowords of work space, and a built-in magnetic-tape drive. Interface it to the DPO via the P7001/IEEE 488 Interface, and you have an economical yet powerful waveform processing system.

**IEEE 488 is an industry hardware standard. Operational protocols and specific software instructions may vary from manufacturer to manufacturer. DPO operation through the P7001/IEEE 488 Interface with controllers other than the TEKTRONIX 4051 Graphic System may require the development of specific driver software.*

New Software Support Packages for TEK SPS BASIC

Two new software support packages are available for use with TEK SPS BASIC. These support packages allow the user to write unique drivers and commands which can be implemented under TEK SPS BASIC to control specialized instruments and perform specialized processing.

TEK SPS BASIC High-Level Support Package (CP89771)

The High-Level Support Package for TEK SPS BASIC Software enables users to write drivers with BASIC language commands. This may be used to control and handle data to and from unique instruments (i.e., instruments not furnished as part of the original Tektronix package or system) or other system peripherals not supported by TEK SPS BASIC Software. In this way, software control of the instrument or device can be accomplished under TEK SPS BASIC. Standard medium is flexible disk.

OPTIONS:

01 TEK SPS BASIC High-Level Support Package on cartridge disk

02 TEK SPS BASIC High-Level Support Package on cassette

05 Integrate packages on minimum number of media

21 Software license (binary) for up to 10 systems registered over one year

25 Software license (binary) for up to 50 systems registered over two years

TEK SPS BASIC Assembly-Level Support Package (CP89772)

The Assembly-Level Support Package for TEK SPS BASIC Software enables user-written commands and drivers to be implemented in assembly language for greater operating speed and memory economy. The package is intended to be used by an experienced programmer who is familiar with developing assembly-language programs. Special debugging, linking, and assembling commands are provided along with example listings of TEK SPS BASIC Software drivers and command source programs. Information describing how to write drivers and non-resident commands using DEC (RT-11)* MACRO Assembly Language is also provided. Users of this package must have a DEC RT-11 software license. Standard medium is flexible disk.

OPTIONS:

01 TEK SPS BASIC Assembly-Level Support Package on cartridge disk

02 TEK SPS BASIC Assembly-Level Support Package on cassette

05 Integrate packages on minimum number of media

21 Software license (binary) for up to 10 systems registered over one year

25 Software license (binary) for up to 50 systems registered over two years

For further information about either of these new packages, contact your local Tektronix Field Office or representative or check the appropriate block on the reply card.

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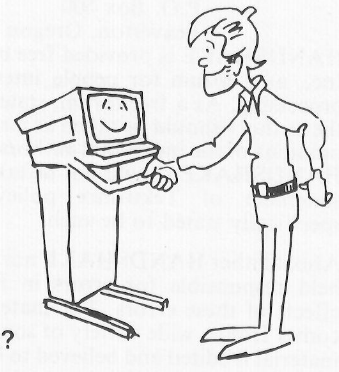
*Registered trademark of Digital Equipment Corporation.



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AX-3747