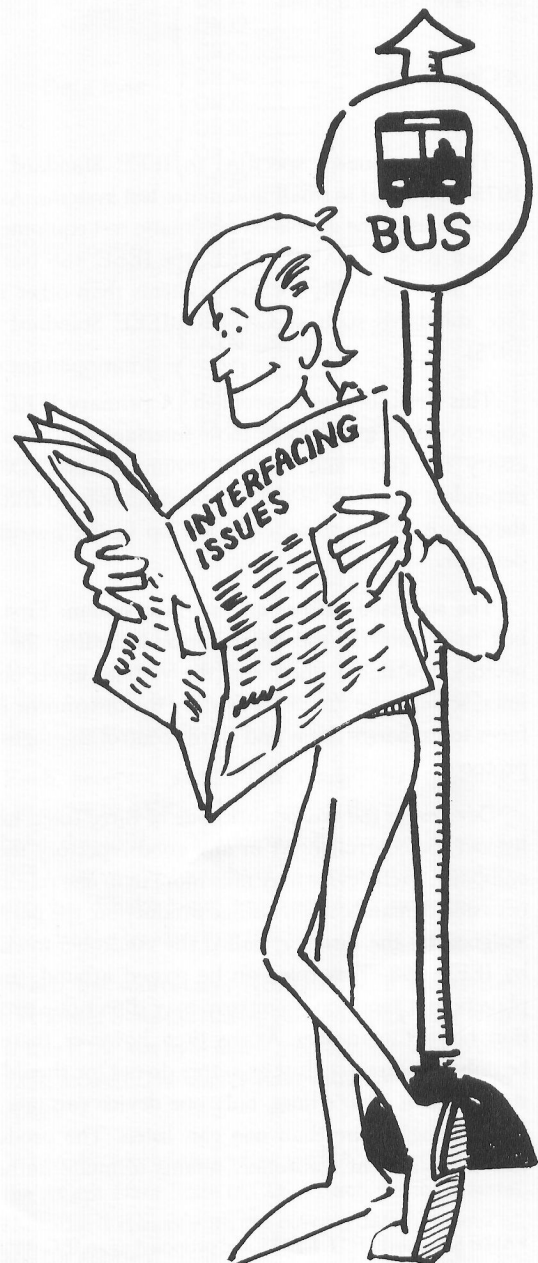


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Getting on the IEEE 488 Bus?

*Make Sure
It's Going Your Way . . .*



The IEEE 488 Bus — Going Your Way?

Many designers and electronic instrument manufacturers are getting on the IEEE 488 bus and many more are about to board. But as with any bus system, there are a few unhappy riders.

IEEE 488 critics are asking questions such as, "Sure I won't get smoke if the instruments I connect are IEEE 488-compatible, but will they work?" And, "Even if I carefully select instruments for the capabilities I need, will they speak the same language?" And, "How can I be sure the instruments I choose for my system all implement the optional features in the standard that I need?"

A lot of the confusion comes from too little understanding of the standard. So let's find out what the standard is and what it is not.

A Closer Look

The bus concept specified in IEEE Standard 488-1975* is partial to small automatic test systems. As was pointed out in the article on automatic test equipment in the last issue of HANDSHAKE, the IEEE 488 bus provides more flexibility for such systems than other interface standards such as CAMAC (IEEE Standard 583-1975).

This flexibility is no accident. A primary IEEE 488 objective is to specify only those interface functions necessary for clear and orderly communication. Device-dependent functions — what the instruments do and how they do it — are specifically left up to the instrument designer.

The standard defines an interface system: First, the bus that connects the instruments, including the connectors, the signal lines, and the voltage levels on the lines; second, the functions used by the instrument interfaces to exchange data; and third, control messages and protocols.

Devices on the bus perform one of three roles: talker, listener, or controller. As in any good repertory theater company, each device may take more than one role as the occasion demands. As in a stage production, the parts are assigned by the director, called the controller-in-charge by IEEE 488. This role can be passed around, just as players in a repertory company may direct one production, but act in another. At any time, however, there can be only one director. Just as actors do not (or should not) step on each other's lines, only one device can talk at a time, though more than one can listen. The producer, called the system controller, retains ultimate authority

and can double as director — that is, be both system controller and controller-in-charge.

To stage an IEEE 488 production, we must select the skills needed by the actors. These are the interface functions defined by the standard;

- Source Handshake
- Acceptor Handshake
- Talker
- Listener
- Service Request
- Remote Local
- Parallel Poll
- Device Clear
- Device Trigger
- Controller

The designer can choose from a list of subsets of these functions to put together the most cost-effective combination. A collection of subsets sounds strange until you understand that it's just a shorthand way of noting the device's interface functions. C0, for instance, states that a device has zero capability as a controller. DT1 means a device can be triggered to perform a designer-chosen function when it receives the device trigger interface message.

To see how these interface functions are used on the bus, let's take another look at the diagram of the bus signal lines shown in the previous HANDSHAKE (Fig. 1). The 16 lines comprise three groups: data, handshake, and interface management.

The eight data lines are used together to transfer eight-bit bytes, hence the term "bit-parallel, byte-serial interface."

The handshake lines control an asynchronous, three-wire handshake. DAV (Data Valid) is asserted by the transmitting device, and NRFD (Not Ready For Data) and NDAC (Not Data ACcepted) are asserted by the receiving device to pace the dialogue on the bus.

The interface management lines have several uses. ATN (ATtention) is like the director's megaphone: when the controller-in-charge asserts ATN, everyone pays attention. Two lines are reserved for the system controller: REN (Remote ENable) is asserted for remote control of devices on the bus, and IFC (InterFace Clear) tells all devices to reset their interface functions. SRQ (Service ReQuest) can be asserted by any device to interrupt the controller. EOI (End Or Identify) indicates the end of a data transfer, but can also be used with ATN in a special polling mode.

*ANSI Standard MC 1.1-1975 and proposed as an IEC standard.

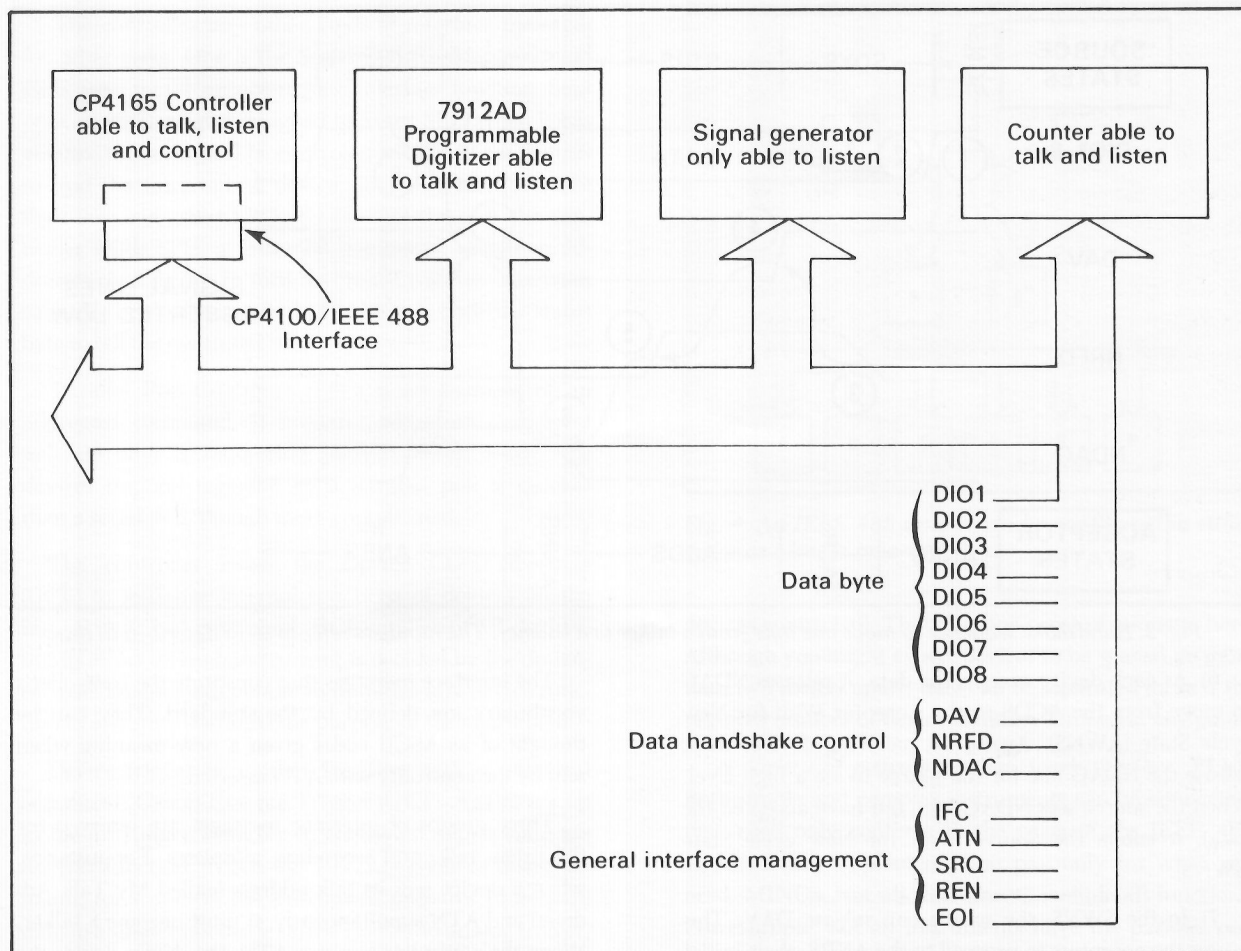


Fig. 1. IEEE 488 bus organization showing the bus signal lines and some typical bus instruments.

A Byte at a Time

How are these lines used by the interface functions? Let's take the source and acceptor handshakes first. Actually, they are two parts of the same handshake. Figure 2 shows the states of these lines as they are set by a talker using the source handshake and a listener using the acceptor handshake. Note that the timing diagram relates the electrical signals on the bus to the states of the source and acceptor handshakes. By looking at both, it may be easier to grasp the sequence of the interlocked handshakes than it is to absorb the infamous state diagrams in the standard.

1) To begin, the source (talker) goes to the Source GeNerate State (SGNS). In this state, the source is not asserting a data byte on the data lines or DAV. When no bus driver is asserting a line, it rises to the high level set by the bus terminating network. The acceptors (listeners) are in the Acceptor Not Ready State (ANRS), asserting both NRFD and NDAC. In this condition, NRFD and NDAC are low.

2) The source sets the data byte on the data lines and enters the Source DelaY State (SDYS). The source waits for the data to settle on the lines and for all acceptors to reach the ACceptor Ready State (ACRS).

3) Each acceptor says, "I'm ready" by releasing NRFD to move to ACRS. This is one of the points in the handshake designed to accommodate slower listeners. The NRFD line can be thought of as a wired-OR input to the source handshake logic. Any acceptor can delay the source handshake by asserting this line.

4) When the source sees NRFD high, it enters the Source TRansfer State (STRS) by validating the data with DAV. If this is the last byte in the message, the source can assert EOI, as well. The source then waits for the data to be accepted.

5) When the receiving devices see DAV asserted, they go to the ACcept Data State (ACDS). Each device asserts NRFD because it is busy with the current data byte and is not ready for another.

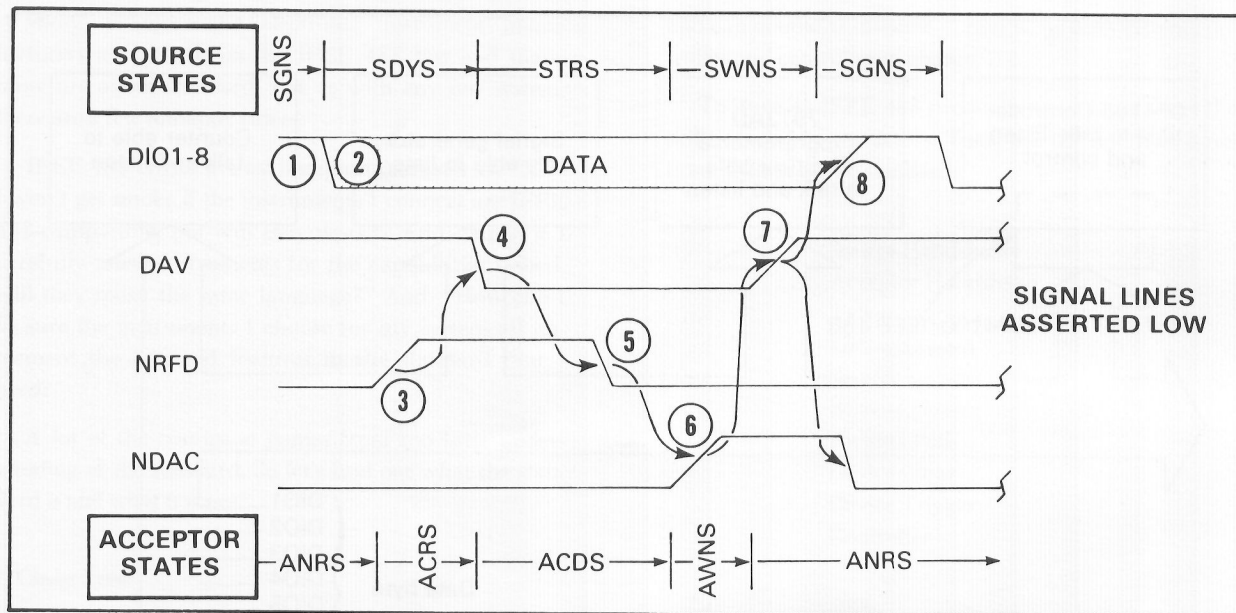


Fig. 2. Handshake sequence to move one byte from a talker to a listener. The numbers refer to steps described in text.

6) As each device accepts the data, it releases NDAC to move from the ACDS to the Acceptor Wait for New cycle State (AWNS). Again, all receiving devices must release the NDAC line for the source to see a high level. When the source sees NDAC high (all have accepted the data), it enters the Source Wait for New cycle State (SWNS).

7) In the SWNS, the source can release DAV. This causes the acceptors to proceed to the ANRS, their initial state in the handshake. In ANRS, they assert NDAC.

8) The source continues to the SGNS, its initial state in the handshake. In this state, it can change the data lines to prepare a new byte for transmission.

This is a typical sequence. The exact sequence is defined by the state diagrams in the standard. The only requirement is that if what happens on the signal lines differs from the above sequence, it must still conform to the state diagrams.

Who's in Charge Here?

We've just staged a dialogue between a talker and listener(s) using the source and acceptor handshakes, but they're not the only ones allowed to use the handshakes. The source handshake is also used by the controller-in-charge to send system control messages; these are called interface messages to distinguish them from device-dependent messages sent from talkers to listeners (see Fig. 3). Remember the director's megaphone — ATN? The controller asserts ATN to get the attention of all devices on the bus and then uses the source handshake to send interface messages on the data lines.

The interface messages that constitute the controller's vocabulary are defined by the standard. They can be thought of as ASCII codes given a new meaning when sent by the controller with ATN asserted.

Three groups of interface messages are reserved for the listen, talk, and secondary addresses. For instance, when a device sees its talk address (called My Talk Address) and ATN simultaneously, it must become a talker. When the controller removes ATN, the device begins the source handshake to transmit its data. Similarly, My Listen Address and ATN tell a device to listen to the data sent by a talker. Secondary addresses provide unique addresses for devices that share single listen or talk address. In the TEKTRONIX 7912AD Programmable Digitizer, for example, secondary addresses select among the mainframe and plug-ins, all of which share the same IEEE 488 bus interface.

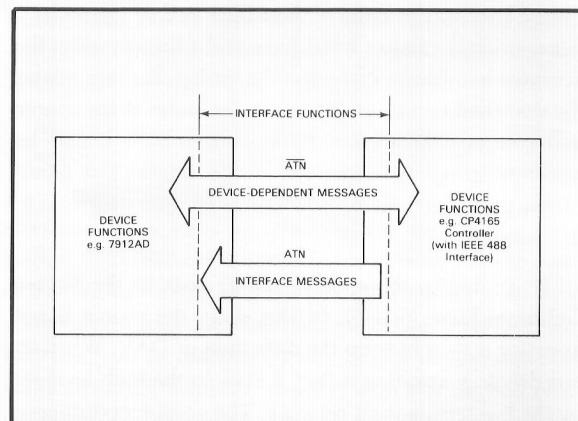


Fig. 3. The ATN line is used to distinguish between interface (system control) and device-dependent messages.

The controller uses other kinds of interface messages for other tasks. One is the Serial Poll Enable command (SPE) used by the service request interface function. Suppose an instrument is designed to assert SRQ when it has acquired some data. The controller must poll the devices to find the interrupting device since any one (or more than one) can assert SRQ. To conduct the poll, the controller sends SPE, a universal command, and then addresses each device in turn and reads a status byte from each. If the device asserted SRQ, it can code the status byte to tell the controller why.

Parallel Poll Configure (PPC) is an example of an addressed command. It prepares addressed devices to indicate who is requesting service. When ready, the devices respond together; so a parallel poll is quicker than a serial poll, though more complicated.

The controller issues the Device CLear message (DCL) to initialize internal functions of devices on the bus. A universal command, DCL applies to all devices, but its effect on each instrument is decided by the designer. The designer can choose to initialize any device function to any state that suits the purpose of the instrument.

Device trigger is another function with a universal command; Group Execute Trigger (GET). Again, it's up to the instrument designer to choose an appropriate use for this function. When the 7912AD receives this command, for instance, the instrument prepares to acquire data in a single-shot mode on the next valid analog trigger.

So far, in addition to reviewing some of the interface messages, we've used all the control lines except two, REN and IFC. These lines are reserved for the system controller. Just as the producer holds the ultimate authority in the theater, the system controller holds ultimate authority on the bus with these two lines. Setting REN raises the curtain; that is, it enables remote operation of the devices on the bus. Releasing REN brings down the curtain; when REN goes false, all devices must return to local mode. IFC is used by the system controller to call a halt to action on the bus; talkers and listeners are reset to receive commands from the controller-in-charge, a role that automatically reverts to the system controller following an interface clear.

Adding It Up

With this introduction to the IEEE 488 concept, let's add up the pluses and minuses for the system designer.

IEEE 488 is a parallel system. PLUS: Flexible configuration — it works either in a star or linear configuration (Fig. 4). **MINUS:** Distance is limited in either configuration to 20 meters (about 65 feet). To maintain the bus electrical characteristics, a device load must be connected for each two meters of cable (no more than 15

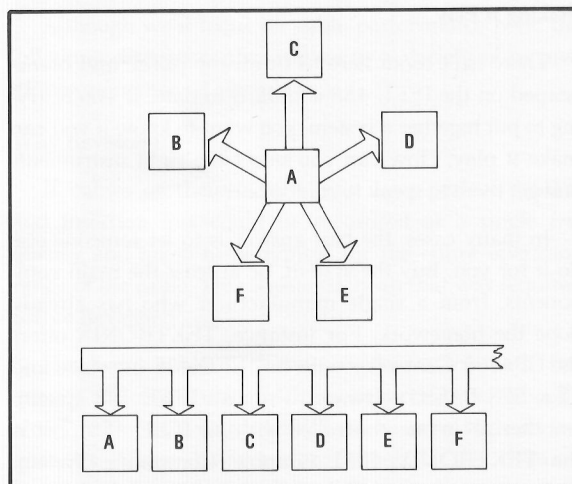


Fig. 4. An IEEE 488 system can be configured in either a star or a linear manner.

devices connected). There's a fine point of etiquette here. Although you might expect devices to be spaced no more than two meters apart, they can be separated more if the required number of device loads are lumped at any point.

A variety of instruments can work together. PLUS: Both simple and complex instruments can be connected; they need only conform to the parts of the IEEE 488 standard they implement. You pay only for what you need. **MINUS:** Not all instruments include all functions. For example, not all instruments have the parallel poll function. The device trigger is another function that may be missing. Some instruments assert EOI when they are finished talking, others do not. They may send a special character or just quit talking, leaving it up to the controller to decide how long to wait before jumping in to take control.

Asynchronous data transfer. PLUS: The handshake allows both slow and fast talkers to play together on the bus. **MINUS:** Everyone goes at the pace of the slowest device. As long as the race belongs not to the swift, but to the steady, that's all right. But that may mean a data rate of only 20 kilobytes per second, it may mean 10 kilobytes per second, or even less. Attention to design is required to get the device interfaces to go faster; it can be done, but it only takes one slowpoke to hold all devices back.

Common data byte size. PLUS: Eight bits is a useful size for data. It fits data processing that operates on words that are eight bits in length (or multiples of eight bits), as is often the case. **MINUS:** Eight-bit bytes are unhandy if your data happens to be nine bits wide, or your controller is a 12-bit machine.

Standard implementation. PLUS: The IEEE 488 electrical characteristics rely on the most common logic family — TTL. **MINUS:** The system is limited to medium speeds; ECL could go faster but doesn't fit the spec.

Making It Play

There isn't room here to fit all the praise and blame heaped on the IEEE 488 standard to date. If you're trying to put together a system, you want to know if you can make it play. How can you select the right instruments and get them to speak to each other?

In many cases, the best answer is to let someone else do it for you. Buy the system, or at least the main components, from a single manufacturer who has already done the homework. For instance, TEKTRONIX offers the CP4165 Controller with an IEEE 488 interface and TEK SPS BASIC software to run an IEEE 488 system. Another all-in-one controller with an IEEE 488 port is the TEKTRONIX 4051 Graphic Computing System. Either way, you're off to a good start because the software that remains to be written amounts to filling in the blanks with commands and parameters specific to the instruments in the system. TEK SPS BASIC commands for TEKTRONIX acquisition instruments, such as the 7912AD, make it even easier with high-level software that needs no fill-ins.

Another advantage of buying from one manufacturer is that the system includes pieces that were meant to play together. Some of the minuses mentioned above are removed and some of the pluses enhanced.

But perhaps you want to put the system together yourself for any of a number of reasons. If doing it yourself includes designing an interface or writing extensive software, there's no way around reading the standard. Just as it's expected that a federal judge understands the Constitution, it's expected that an IEEE 488 designer understands the standard. It's dry reading, but it is thorough and complete. Be assured you'll eventually find the fine points. For instance, one more than half the number of instruments connected to the bus must be powered-up to maintain the bus termination. Some users found this out on their own when they discovered intermittents on the SRQ line, but they could have read it first in the standard.

The standard is thorough, but as designers continue to work with it, more questions are going to be raised. We'd like to help by providing a forum for IEEE 488 users. In the next issue of HANDSHAKE we'll begin by making some popular combinations of instruments play on the bus and also take up some of the questions that are often asked about the standard to try to make it work for you.



By Jim Kimball, HANDSHAKE Staff

Interfacing Issues . . .

. . . New Column to Start in HANDSHAKE

Beginning with the spring, 1978, issue, a new column entitled "Interfacing Issues" is slated to appear in HANDSHAKE. This column will present interfacing examples and deal with specific problems caused by the proliferation of instrument interfacing choices.

Since interest among instrument designers and users seems greatest in the IEEE 488 bus, the column will be slanted in this direction. In the first few columns, we plan to deal with interfacing Tektronix instruments to other IEEE 488 compatible instruments and controllers. But we welcome your contributions and suggestions for future columns. You can provide some of the questions to be dealt with in "Interfacing Issues," and we're pretty sure you can provide some of the answers too. Although the column cannot act as a designer for frustrated interface engineers, it can pass on successful interfacing ideas. These need not be limited to the IEEE 488 bus, but can deal with any of the other common interface systems.



So, if you are having interfacing problems, keep your eye on this spot. And, if you have a solution to an interfacing problem, send it to HANDSHAKE (Outside the USA, contact your local Tektronix Representative). We'll be glad to relay the good news to the rest of the signal processing world.

Swept RF Measurements — A Realistic Approach

If you are involved in the manufacture, integration, or maintenance of microwave cables and components, your job has been greatly affected by Revision E to MIL-C-17 (the procurement document for most coaxial cable used by the United States Government). This revision contains the first significant changes in cable performance requirements in many years. Originally, MIL-C-17 allowed testing at a few specific frequencies. Now, however, Revision E (effective March 15, 1977) requires, among other new tests, swept-frequency measurements on most types of coaxial cables, including all 50-ohm cables.

More inclusive quality control techniques from MIL-C-17E will filter into the general industry. Contributing to this will be the new "M" designations assigned to cables under MIL-C-17E control — "RC" cables may still be offered, but their quality will no longer be controlled by MIL specification.

With a better product resulting from all this, some of those havoc-raising "glitches" which often appear in many microwave systems will be eliminated. Thus, in order to ensure quality, many cable buyers will probably specify the new "M" cables or their equivalent.

So, no matter what sector of the cable or component industry you inhabit, it's certainly worth considering the whys and wherefores of the swept-frequency measurements required by MIL-C-17E. And since it is likely your new cable data documentation will be presented in a manner similar to Figure 1, let's consider how this can be quickly and accurately done with an automated waveform processing system based on the TEKTRONIX Digital Processing Oscilloscope (DPO) and TEK SPS BASIC software.

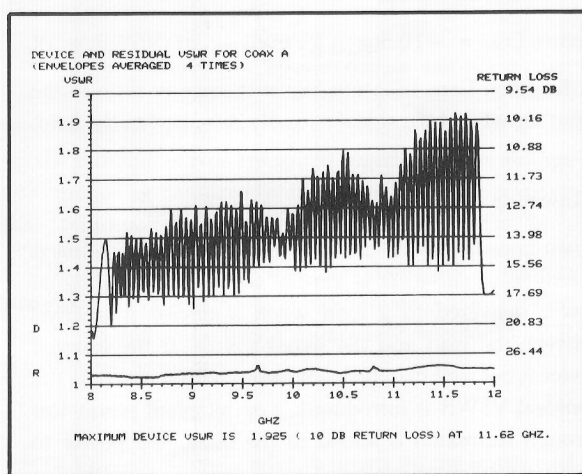


Fig. 1. Sample output from an automated swept-frequency VSWR test setup using a TEKTRONIX Digital Processing Oscilloscope. The "D" waveform is the VSWR of the device under test over a range of 8 to 12 GHz. The "R" waveform is test setup VSWR, referred to generally as residual.

Although we'll focus on cable performance here, the following discussion also applies to a variety of passive RF components and assemblies.

Why Revision E?

If cables or their installations were perfect, VSWR and insertion loss could be measured at a single frequency and taken to be typical for the entire operating range of the cable. This is essentially all that was required before Revision E.

However, cable performance does vary with frequency. Manufacturing defects occurring periodically along cables can cause VSWR to be very high at frequencies whose half-wavelength equals the distance between defects. Installation defects such as overtight cable clamps constricting the cable diameter, or cable frayed, bent, or nicked by a vibrating or flexing supporting structure can cause high VSWR or insertion loss spikes. So, a reasonable picture of VSWR and insertion loss over a cable's operating range requires measurements at a large number of separate frequencies. But how many point-by-point measurements are enough?

In the past, single-frequency and point-by-point VSWR and insertion loss tests often qualified cables that were actually defective at a few untested frequencies. Because of this, it has become necessary to go to swept-frequency measurements. With swept-frequency measurements there are no gaps between test frequencies where narrow-band VSWR spikes can reside undetected.

Swept-Frequency Measurements — The Hard Way.

VSWR. Although two test setups are prevalent — a slotted line and VSWR bridge — we'll emphasize the slotted-line technique. It is the most commonly used and provides the most consistent performance for frequencies above 2 GHz.

A slotted-line test setup is illustrated in Figure 2. First, let's discuss the test as set up for manual processing.

The output of an amplitude-leveled sweep-frequency generator is transmitted through the slotted line and into the cable being tested. Any standing waves occurring in the cable also appear in the slotted line. A probe in the slotted line picks up the standing wave voltage level at the probe position. This voltage is then detected, usually by a crystal detector, and displayed on a storage oscilloscope.

The X-Y mode of operation is one traditional approach to displaying reflection waveforms; however, it is not compatible with DPO storage operations and raises further problems when switched band sweepers are employed. A better approach is to externally trigger the oscilloscope horizontal sweep with the sweep generator's blanking output.

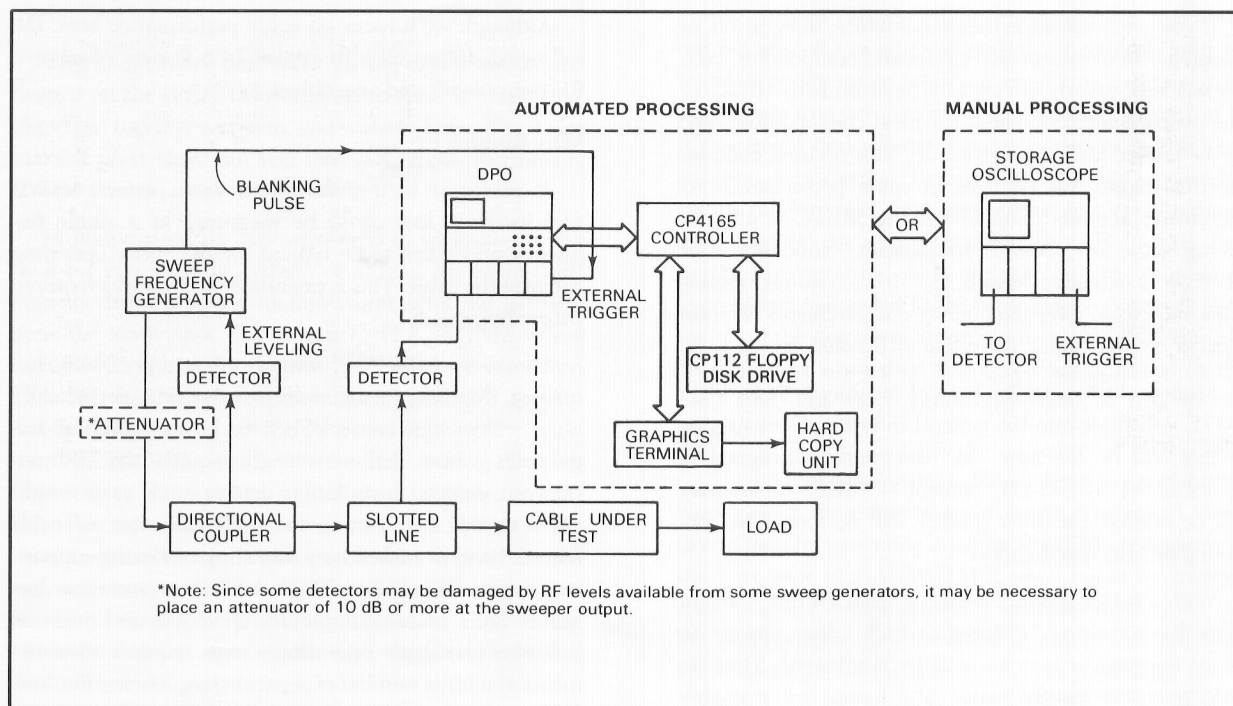


Fig. 2. VSWR test system for manual or automated processing.

Which Tests Are We Making?

VSWR (voltage standing-wave ratio) is the most commonly used cable performance parameter. Insertion loss (or attenuation) runs a close second in importance.

VSWR. VSWR is, essentially, a measure of the electrical uniformity of a cable and how well it is matched by its terminating load. Mismatches reflect portions of the signal back along the cable. These reflections constructively or destructively interfere with the transmitted signal, producing a standing-wave pattern. This standing wave contains a voltage maximum and a voltage minimum at a given frequency. VSWR is then computed as the ratio of the maximum and minimum standing-wave voltages:

$$\text{VSWR} = E_{\text{max}} / E_{\text{min}}$$

where ideal VSWR is unity, and worst-case VSWR is infinity. VSWR may also be expressed in decibels as:

$$\text{SWR (dB)} = 20 \log_{10} \text{VSWR},$$

or as a return-loss quantity in decibels which has the following relationship:

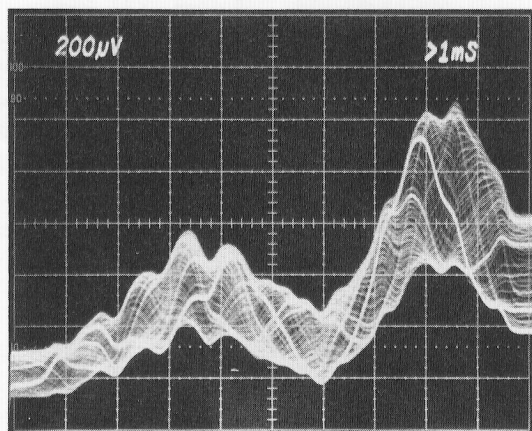
$$\text{Return Loss} = -10 \log_{10} [(VSWR - 1) / (VSWR + 1)].$$

Insertion Loss. Insertion loss is the power ratio of the input signal and the signal actually delivered to the load, or:

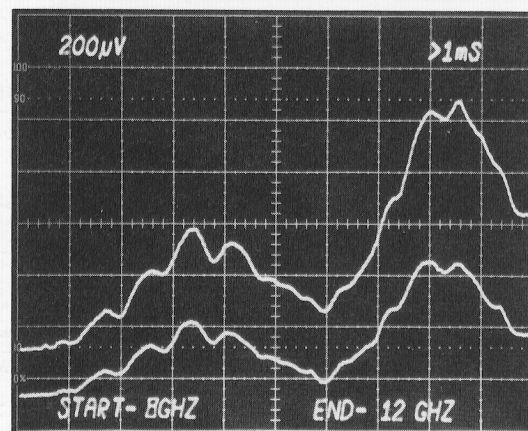
$$\text{Insertion Loss} = 10 \log_{10} (P_{\text{output}} / P_{\text{input}}).$$

When impedances are carefully matched, insertion loss is strictly dissipative. It is simply the decrease in signal power delivered to a load when a device is inserted between the load and the signal source. If the inserted device is not well matched, a mismatch loss caused by the nonideal VSWR is introduced. Any reflected power lost through mismatch is added to the dissipated power to obtain a total insertion loss.

In well designed systems, VSWR is held to a minimum by careful matching and the reflected component of insertion loss is negligible. Insertion loss then becomes synonymous with attenuation.



a. Time exposure showing standing-wave variations as a probe is moved along a slotted line.



b. Upper and Lower envelopes determined from "a" by the ENVDPO command.

Fig. 3. Example of ENVDPO operating on swept-frequency standing waves detected with a slotted line.

By adjusting oscilloscope sweep duration, the display can be calibrated so that the beginning of the swept spectrum occurs at the left edge of the display and the end occurs at the right edge. A sweep rate of 50 or 60 times per second is enough to give a stable display of a swept reflection waveform. This waveform represents the detected voltage, plotted across the frequency band, at a single point on the slotted line.

To get VSWR data, a zero reference for the standing waves is required. The zero reference is simply a ground trace adjusted to coincide with the bottom graticule line on the oscilloscope. This remains a valid reference as long as the vertical controls are not readjusted. The probe is then moved slowly in one direction along the slotted line for at least one-half the wavelength of the lowest frequency swept. This results in a buildup of standing waves for each frequency at each point on the slotted line. When all the standing waves are stored together on the storage oscilloscope (or captured by time-exposure photography), they form a composite waveform like the one in Fig. 3a.

Obtaining VSWR data from this composite waveform involves a lot of repetitious computations. Assuming that the slotted-line probe uses a square-law detector, VSWR is calculated as follows:

$$\text{VSWR} = (V_{\max}/V_{\min})^{1/2},$$

where V_{\max} and V_{\min} refer to points on the upper and lower envelopes, respectively, of the composite waveform at a specific frequency. Each VSWR computed is for a different frequency. By repeating the ratioing process at several frequency points across the display, enough VSWR values can be computed to make a VSWR versus frequency plot. Or, you can focus on abnormally high

VSWR by simply noting areas of abnormally wide envelope separation. Better yet, you can automate and let a digital controller do all the searching, counting, and computing.

Insertion Loss. Figure 4 illustrates an insertion loss test setup. Again, we'll look at the manual processing version first.

Since a directional coupler, which provides a low-level sample of the incident signal, and a square-law detector are required at each port to sense input and output power, insertion loss is computed using the detector outputs:

$$\text{Insertion Loss} = 10 \log_{10} (B' / A').$$

This result contains system insertion loss as well as the cable loss, so system insertion loss must be subtracted out.

This can be done by removing the cable under test and connecting ports A and B directly together, giving a reference (system) insertion loss:

$$\text{Reference} = 10 \log_{10} (B'_r / A'_r).$$

Next, insert the cable into the test system to obtain total insertion loss:

$$\text{Total} = 10 \log_{10} (B'_t / A'_t).$$

The cable insertion loss is then the difference between the total and the reference, which can be expressed as a ratio:

$$\text{Cable Insertion Loss} = 10 \log_{10} \left(\frac{B'_t / A'_t}{B'_r / A'_r} \right)$$

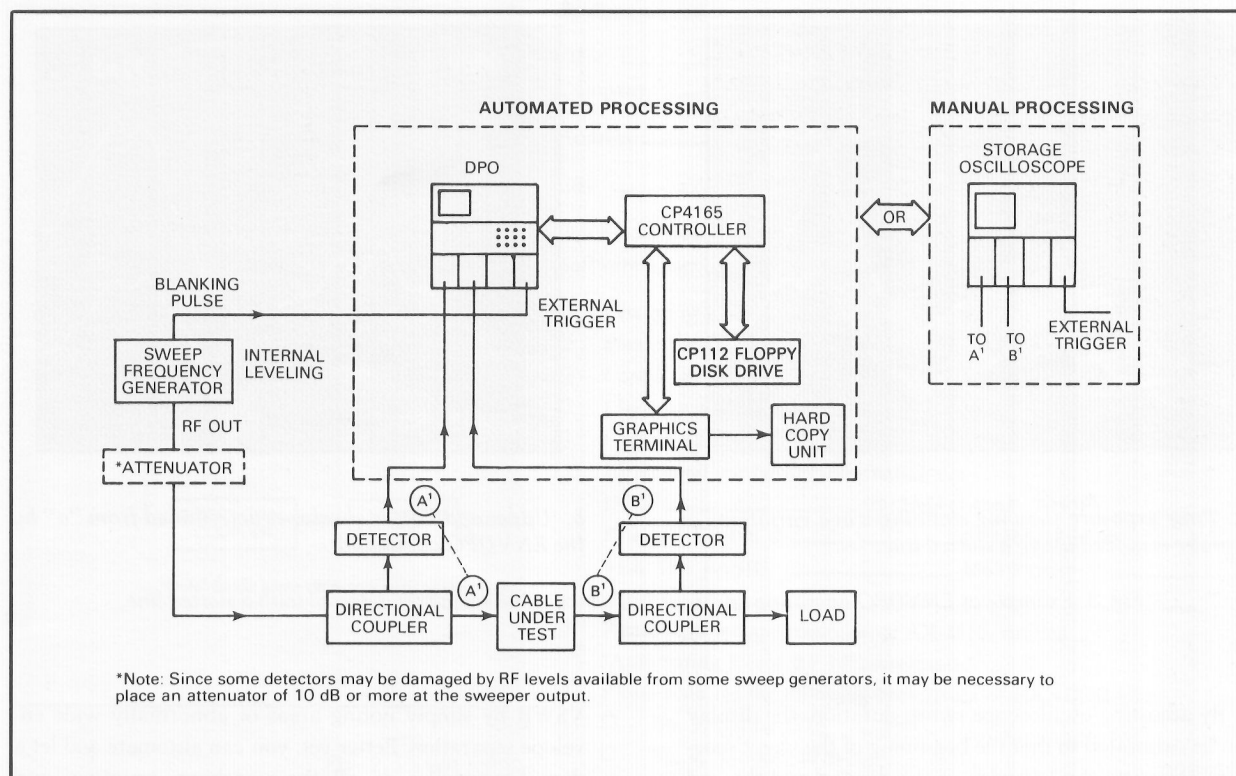


Fig. 4. Insertion loss test system for manual or automated processing.

Removing the reference cancels any losses contributed by the test setup. Also, any input level variations at A are accounted for in the calculations because the input and output data are acquired simultaneously.

Since the data are taken visually from the oscilloscope display and the swept insertion loss computations are done by hand, the fact that there are four swept-frequency waveforms that must be point-by-point ratioed across the display says it's time for number-crunching automation. And suppose the VSWR and insertion loss tests must be made from 2 - 18 GHz. To get any acceptable visual resolution, it would be necessary to make separate measurements over four separate bands, each 4 GHz wide. And that's only for one cable!

What's Involved In Automating?

The chief advantages of an automated system over a manual one are rapid throughput and high repeatability with substantially reduced measurement error. The hardware solution involves the use of instruments with individual accuracies better than the sought-after end accuracy. The software solution involves measurement techniques that at least preserve and preferably enhance the instrument accuracies.

Both VSWR and insertion loss measurements can be automated by replacing the storage oscilloscope with a

waveform processing system containing two key elements: the TEKTRONIX Digital Processing Oscilloscope (with an appropriate controller) and TEK SPS BASIC software (See Figures 2 and 4).

DPO. The first step in automation is to convert the swept standing-wave and insertion loss signals into a format the computer can work on. The DPO consists of a high quality laboratory oscilloscope enhanced by the addition of the P7001 Processor. When controlled by the appropriate software, such as TEK SPS BASIC, the DPO digitizes the acquired waveforms and stores them in 512-element memory arrays. The digitizing is accomplished with ten-bit vertical resolution over 512 horizontal waveform elements. Compare that accuracy to what an operator could successfully distinguish visually!

After all the necessary signals and their grounds have been acquired, they can be transferred from the DPO memory to the system controller for processing into VSWR or insertion loss data.

Proper scaling of the digitized data arrays is accomplished by using stored readout and ground reference information. Software does all the manipulations and calculations you would normally do with oscilloscope photos, calipers, pencils, and patience.

Software. One suggested approach to VSWR and insertion loss measurements is flow-diagrammed in Figure 5. These operations could conceivably be handled by any software system compatible with the digitizer being used. However, specialized signal processing software, like TEK SPS BASIC, makes many necessary operations very convenient (such as scale-factor manipulation and single-statement array processing).

Now, let's briefly discuss the blocks in Figure 5.

Block 1. This is the point where basic test information is provided to the program. Questions are asked and the answers are stored for later use in guiding program execution. Some sample questions are: How many sweep ranges is the frequency sweeper using? What are the upper and lower limits of the RF frequency range for VSWR? Do you want device residual VSWR graphed also?

Block 2. Often, a single-band sweep generator will be insufficient to cover the required frequency ranges. Band switching is a solution, but the band-switching intervals must be located. The test setup allows for several methods. The measurement program can provide for operator inputs of the band's beginning and ending points. Or a cross-hair cursor can be displayed on the terminal screen. Thumbwheels on the terminal align the cursor with the band edges and software reads the data values at the cursor position. A third approach is a programmed search for the sweep blanking intervals using the CRS function of TEK SPS BASIC. The particular method employed depends upon the band-switching characteristics of the sweep generator used.

Block 3. At this point, system calibration waveforms (for residual VSWR and system insertion loss) are captured and processed. Also, if the swept waveforms contain band-switching intervals, the previously acquired band-edge information is used to remove the blanked intervals and tie the band edges together so the data represents a single, continuous swept waveform.

The system calibration waveforms for insertion loss measurement are stable with time, so it is possible to use the signal averaging command from the DPO Driver Package to reduce additive noise. The averaging process reinforces stable signal components and averages out random signal variations (noise). The more averaging you do, the more improvement you get in signal-to-noise ratio.

A different process, however, is required for acquiring residual VSWR with a slotted line. This is because the acquired reflection signal is not stable with time — it changes as you move the slotted-line probe. So, a special method is needed to first define the upper and lower envelopes of this changing reflection signal.

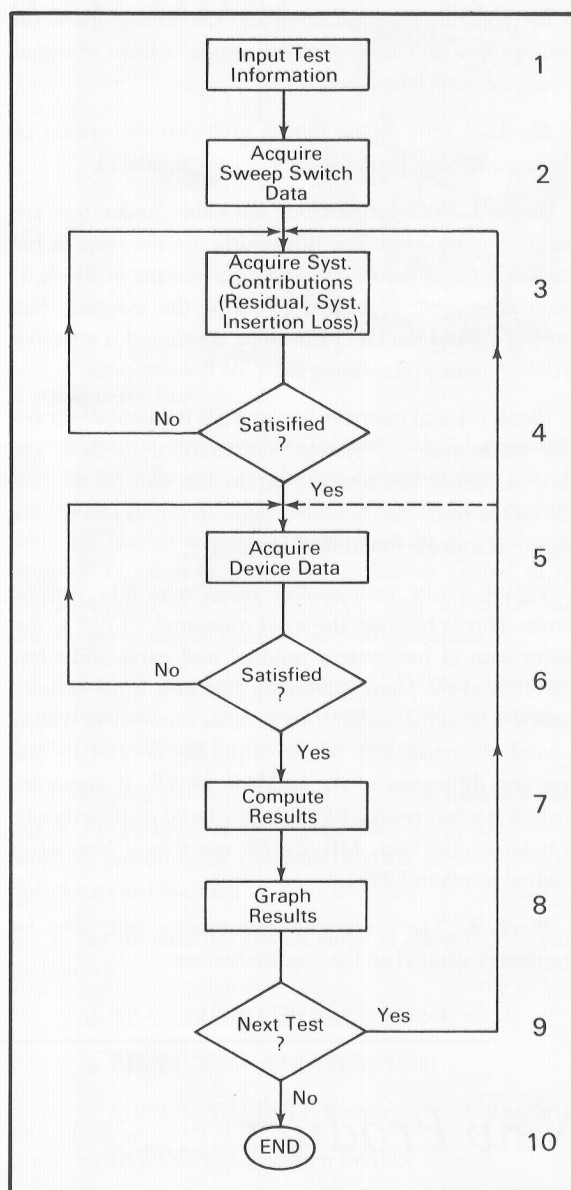


Fig. 5. A suggested software approach to VSWR and insertion loss measurements.

A unique approach to determining VSWR employs the DPO Envelope command (ENVDPO), which is a supplemental module for use with the DPO Driver Package. The non-resident ENVDPO command continuously stores the incoming standing-wave in a DPO memory array and finds the stored signal's point-by-point maxima and minima. These are stored in two more arrays as upper (maxima) and lower (minima) envelopes representing the variation limits reached by the incoming standing-wave signal (illustrated in Figure 3). The residual VSWR of the slotted line setup can then be computed:

$$\text{Residual VSWR} = (\text{upper envelope} / \text{lower envelope})^{1/2}$$

By repeating the acquisition and enveloping operation several times and averaging the results, a form of signal averaging is accomplished.

Blocks 4 & 6. These blocks give you the option of either going back for more data or moving ahead.

Block 5. Waveforms from the cable under test are acquired in this step. The procedures are the same as for acquiring the system calibration waveforms in Block 3. Signal averaging is needed to refine the insertion loss waveforms and the DPO Envelope command is effective in determining and refining the VSWR waveforms.

Block 7. Final insertion loss or VSWR calculations are now made and any system contributions to them are removed. Since test setup insertion loss can be directly subtracted from the measured total, insertion loss results appear as a single function of frequency.


VSWR results, on the other hand, may take various forms. This is because the total measured VSWR is the vector sum of test system residual and cable-under-test VSWR, and the phase governing this sum is not usually known. The actual cable VSWR exists somewhere within a band of uncertainty whose limits are defined by the sum and difference of the residual VSWR. If you minimize test-setup residual VSWR, the band of uncertainty is reduced. (In fact, MIL-C-17E specifies a test setup residual less than 1.06:1.)

Block 8. The computed test results can now be graphed or printed on the terminal screen.

Blocks 9 & 10. After viewing the measurement results, you can store them on your system storage device or you can output them to a hard copy unit for a permanent record as shown in Figure 1. Then, at Block 9, you can choose to either go back and make another test or end the routine at Block 10.

Here are some additional software considerations to keep in mind. For one, it is generally easier to have two separate programs — one for VSWR and one for insertion loss. This reduces individual program length. But, even with two separate programs, chances are you will still be crowding free memory in the controller unless you segment your program functions so they are loaded in memory only when needed, then cleared. This technique, referred to as "program overlaying," is detailed in the TEK SPS BASIC Software Instruction manual.

Have We Tweaked Your Interest?

You can competitively clear the hurdle of MIL-C-17E. The hardware and software is available off the shelf. The detailed procedures are contained in TEKTRONIX Application Note AX-3810, entitled "Automating Swept RF Measurements." To get a copy of this application note, check the appropriate box on the reply card enclosed in this issue of HANDSHAKE. 

By Walt Robatzek, HANDSHAKE Staff.

New Product . . .

DPO Envelope Command Finds Signal Variation Limits


The DPO Envelope command (ENVDP0) is a supplemental module for use with TEK SPS BASIC software and the Digital Processing Oscilloscope (DPO) Driver Package. It is a non-resident command that continuously stores an incoming signal in a DPO memory array and finds the point-by-point maxima and minima of the signal. The results are stored in two arrays as upper and lower envelopes representing the variation limits reached by the incoming signal.

Typical applications for the ENVDP0 command include swept-frequency VSWR (voltage standing-wave ratio) measurement (see article in this issue), RF burst analysis, evaluation of RF switches, and general signal or spectral monitoring for variation limits.

Flexible disk is the standard medium for the CP55001 DPO Envelope Command. The following options are also available.

OPTION:

- 01 TEK SPS BASIC DPO Envelope Command on cartridge disk
- 02 TEK SPS BASIC DPO Envelope Command on cassette
- 05 Integrate packages on minimum number of media.

For prices and further information on the ENVDP0 module, contact your local Tektronix Field Engineer or Tektronix representative. 

Getting the Most out of TEK BASIC GRAPHICS

For a More Exciting Plot, Try the 4662

The TEK SPS BASIC Graphics Package has already proven its ability to make a variety of plots and graphs via a graphics terminal and hard copy unit. A recently announced interface card (Optional Data Communications Interface) now allows you to direct this output to the TEKTRONIX 4662 plotter, as well. The interface card fits inside the pedestal of a Tektronix 4010-Series Terminal. No special driver software is needed.

The 4662 Interactive Digital Plotter (Fig. 1) can significantly enhance the capability of a signal processing system. For example, multi-waveform graphs can be color coded by simply changing the plotter pen for each new array plotted. Thus a plot simultaneously displaying voltage, current, and power could be coded with green, blue, and red ink, or any of the nine colors of pens available for the 4662.

Making overhead transparencies with the 4662 is also a snap. Insert the transparency just as you would a sheet of paper, and then put the plotter through its paces. A transparency showing actual computer output can be a great aid in presenting research seminars or class lectures.

Since the 4662 is an intelligent plotter (it incorporates a microprocessor) page scaling is easily accomplished with the plotter joystick and margin-set controls. This allows you to change the aspect ratio of a graph or to scale the plots to a different page size without ever touching the terminal. Alphanumeric characters are also scaled in the process. This same feature allows you to create inverted or mirror-image plots. This can be an advantage when plotting overhead transparencies, as explained later.

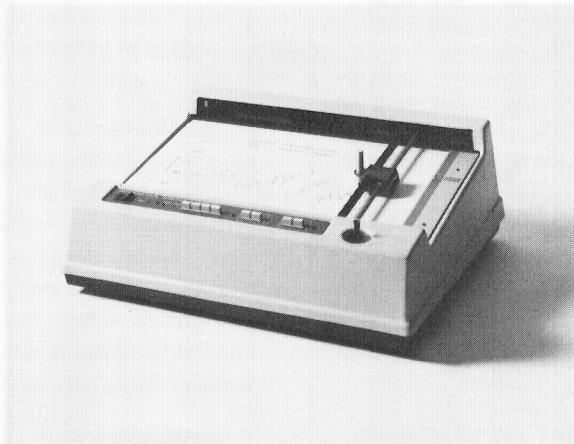


Fig. 1. The TEKTRONIX 4662 Interactive Digital Plotter.



Getting to the Plot

To use the 4662 with a Tektronix signal processing system, the following installation and setup steps must be performed. (The actual installation should be performed only by qualified service personnel.) In the following steps, it is assumed that the terminal is cabled to the minicomputer and that the TTY port interface card (inside the terminal) is set for normal operation.

- 1) Set all straps on the Optional Data Communications Interface as per factory setting. (See the Interface instruction manual for the proper settings.)
- 2) Unplug the terminal and install the interface card inside the pedestal of the 4010-Series terminal. Instructions for installing the interface card are also found in the interface card manual.
- 3) Set the external switch panel of the interface card as follows:
 - a) TRANSMIT BAUD RATE to 1200
 - b) RECEIVE BAUD RATE to 1200
 - c) SUPR/NORM/FULL switch to FULL (Duplex)
 - d) INT/OFF/AUX switch to AUX
- 4) Connect the RS232 cable from the Optional Data Communications Interface to J104 on the back of the 4662.
- 5) Set the four hexadecimal switches on the back panel of the 4662 to:

A:6, B:2, C:2, D:3

Switch D determines the baud rate, which in this case, has been set to 1200. This corresponds to the baud rate set in steps 3a and 3b above.

For some applications it may be necessary to set the baud rate slower than 1200 to prevent the plotter's internal buffer memory from overflowing. Overflow occurs when the computer is supplying data faster than the plotter can process it. Buffer overflow results in a loss of data and is signaled by continuous ringing of the plotter bell.

Overflow does not normally occur unless plotting a lot of alphanumerics preceding long data arrays, but if it does, the situation can usually be remedied by reducing the baud rate to 300 or 600. To set the baud rate to 300, set hexadecimal switch D (on the 4662 back panel) to position 1 and set the baud rate switches (on the Optional Data Communications Interface) to 300 for both transmit and receive. A baud rate of 600 is selected by setting hexadecimal switch D to position 2 and the Interface baud rate switches to 600.

Once the 4662 has been correctly installed, you can power up the terminal, plotter, and computer system. At this time you may want to verify that the 4662 is working properly by exercising the plotter's self-diagnostic routine. This can be done as follows:

1. Latch the plotter LOAD button in the down position. This removes the static charge from the platen, allowing a new sheet of paper to be installed. It also moves the pen carriage to the upper right corner of the platen.

2. Install a clean sheet of paper at the desired position on the platen; then press and release the LOAD button, thereby reactivating the platen hold-down charge.

3. Install a pen of the desired color by inserting the tabs on the pen into the grooves in the pen holder and twisting the pen clockwise.

4. Set the page boundaries of the plotting area with the joystick and SET buttons. Set the lower left boundary by moving the pen to the desired position with the joystick. Then press and hold the SET: LOWER LEFT button until the plotter bell rings. Similarly, to set the upper-right boundary, move the pen to the appropriate position. Then press and hold the SET: UPPER RIGHT button until the plotter bell rings.

5. Call up the plotter self-diagnostics feature (stored in a Read-Only-Memory) by holding the CALL button down until the plotter bell rings twice. The plotter will immediately begin plotting a predetermined set of patterns: a rectangle in the upper-right corner, a sunburst in the lower-left corner and a message in the middle. When the plotter is finished you can remove the sheet by latching the LOAD button down. To install a new sheet of paper or a transparency, repeat steps 1 through 4.

Using the 4662 Under Computer Control

To use the 4662 under computer control, latch the plotter LOCAL button in the down position. All terminal printout will then be produced on the plotter as well as the terminal screen. To disable the plotter, simply unlatch the LOCAL button.

The following program demonstrates the use of the 4662 by plotting three waveforms on the same graticule. Lines 10 through 90 dimension three 512-element waveforms labeled A, B, and C and fill them with simulated data representing current, voltage, and power respectively. Lines 100 through 240 are actually responsible for plotting the data. Since all three waveforms are plotted with respect to the same graticule, the horizontal and vertical scale factors apply to all three waveforms. (Lines 110 and 120 cause a graticule to be displayed which applies to all three waveforms.) The DISPLAY commands at lines 150, 180, and 210 cause each waveform array to be plotted individually. A WAIT command is included after the graticule is generated and before each array is plotted so that a different color pen can be mounted. To exit the WAIT and plot the next waveform, simply press the return key on the terminal. After all waveforms have been plotted, the program ENDS at line 240. (The WAIT command at line 240 prevents READY from appearing on the plot.)

Here is a listing of the program, as plotted on the 4662:

```

LIST
10 WAVEFORM A IS WA(511),SA,HA$,VA$
20 WAVEFORM B IS WB(511),SB,HB$,VB$
30 WAVEFORM C IS WC(511),SC,HC$,VC$
40 SA=.1\SB=.1\SC=.1
50 HA$="MILLISECONDS"\HB$=HA$\HC$=HA$
60 WA=.6283\INT WA,WA
70 WA=SIN(WA*.05)\WA=WA*5
80 DIFF WA,WB\WB=WB*5
90 WC=ABS(WA*WB)
100 PAGE
110 SETGR NOPL
120 GRAPH A,B,C
130 SMOVE 300,750
140 PRINT "INSTANTANEOUS POWER PLOT"
150 WAIT\DISPLAY A
160 SMOVE 925,600
170 PRINT "VOLTS"
180 WAIT\DISPLAY B
190 SMOVE 925,500
200 PRINT "AMPS"
210 WAIT\DISPLAY C
220 SMOVE 925,400
230 PRINT "WATTS"
240 WAIT\END

```

```

READY
*

```

Before entering this program on the terminal, make sure that the plotter LOCAL button is in the up position. This ensures that the program lines will be plotted only on the terminal and not on the plotter. After the program has been entered, type RUN on the terminal, press the plotter LOCAL button, and press the terminal RETURN key. The output from the program is now directed to the 4662 as well as the terminal screen.

If you want to plot the entire graph in one color, simply press the RETURN key to exit each WAIT command. The plotter output will then appear as in Fig. 2. To make the same graph in four colors, change plotter pens and press RETURN after each WAIT occurs.

Variations on a Theme

We stated earlier that mirror images can be plotted with the 4662. This is a particular advantage when making overhead transparencies, since the transparency can be placed ink-down on the projection plate and the image projected normally. Thus you can use a marking pen to highlight or note items on top of the transparency during the presentation. These notes can be erased after each session without disturbing the graph or chart plotted on the other side.

A mirror image can be easily plotted using the 4662 front panel controls. Simply move the pen (via the joystick) to the lower right corner of the desired page area and press the SET: LOWER LEFT button until the plotter bell rings. Then move the pen to the upper left corner of the desired page area and press the SET: UPPER RIGHT button until the bell rings. All incoming data, including alphanumerics, is subsequently plotted in mirror-image format.

The preceding example illustrates some of the possibilities of using a digital plotter with a signal processing system. We have explored only a small part of the 4662's capabilities. Other possibilities include overlaying plots on Smith charts, log-log paper or semi-log paper — tasks that would be difficult to perform by conventional hard-copy techniques.

More sophisticated plots can be generated under program control using a set of plotter control commands. These commands consist of ASCII character strings that allow the computer to control data transfers to and from the plotter, set the character size and font, print the characters at any specified angle, read or write plotter status and control several other plotter functions. The commands can be addressed to any one of up to four plotters tied to the same computer.

If, for example, you wished to emphasize the heading INSTANTANEOUS POWER PLOT (Fig. 2) by making it larger, the program might include these statements:

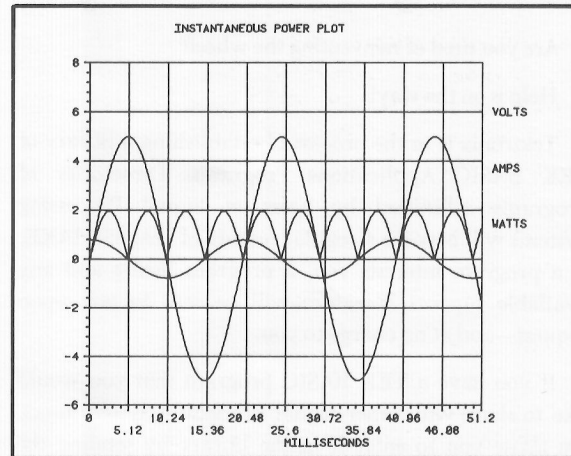


Fig. 2. Example of a multiple-waveform graph plotted on the 4662.

```
135 PRINT ""KAI112,176"
140 PRINT "INSTANTANEOUS POWER PLOT"
145 PRINT ""KAV"
```

When the computer executes line 135, it sends the ASCII character string enclosed in the quotes to the plotter via the terminal. This string sets the character space (width) to 112 units (twice the default width) and the line space (height) to 176 units (twice the default height). Line 145 resets the alpha size to the default size.

Using similar command strings you can print special characters in the heading or rotate the heading to any specified angle.


These simple examples illustrate only a few of the possible 4662 applications. While we have run out of room, perhaps we can explore more plotter applications in future issues.

If you are a user of TEK SPS BASIC software and have discovered a unique or novel application for your plotter, we would like to hear from you.

Within the USA, address your comments to:

HANDSHAKE Editor
Group 157
Tektronix, Inc.
P.O. Box 500
Beaverton, OR.

Outside the USA, address your comments to your local Tektronix Representative.

If you do not yet own a plotter but would like to learn more about its capability, check the appropriate box on the reader-response card. 

By Cliff Morgan, HANDSHAKE Staff

SPS Users' Application Program Library on the Way

Are you tired of reinventing the wheel?

Help is on the way!

Tektronix is in the process of establishing a library of TEK BASIC Applications Programs. Directories of programs submitted by users of Signal Processing Systems will become a regular feature of HANDSHAKE. If a program interests you, a program listing and any available support literature will be sent to you upon request—and at no charge to you.

If you have a TEK BASIC program that you would like to share with other Signal Processing System users, we invite you to enter it in the library by sending the program listing to:

Tektronix, Inc.
SPS S/W Support
94-319
P.O. Box 500
Beaverton, OR 97077

Outside the USA, send your program to us through your local Tektronix representative.

To aid in evaluating and categorizing the program, include a short description — what it does, how it does it, and any special data conditions that it requires. Also, include your name, address and a telephone number where you can be reached should there be any questions about the program.

Your contribution could solve somebody else's problem, and their contribution may solve one of yours.

Edited by Larry Larison

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AX-3853

New Application Note Available

Automating Swept RF Measurements AX-3810

Swept-frequency measurements of coaxial cables are the only way to go since Revision E to MIL-C-17. This application note provides detailed procedures for competitively obtaining excellent throughput and accuracy with an automated test system based on the Tektronix Digital Processing Oscilloscope.

TEK SPS BASIC New Release

TEK SPS BASIC V01-03 is ready.

This new release adds two features to SPS BASIC. In response to the requests for numeric file names, the first character of the name no longer needs to be a letter. File names may now be any combination of up to six alphanumeric characters, A to Z, 1 to 9. Also, the enhanced monitor now supports the PDP* 11/34, 11/34A, and 11/45 floating-point processor units. Users with one of these units will gain about 1600 words of free memory from the shortened software arithmetic routines.

Licensed owners of TEK SPS BASIC V01 may update their software at no cost if it is still under the first-year warranty. Owners of older packages can purchase the new version at nominal cost. For further information, contact your local Tektronix Field Engineer.

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