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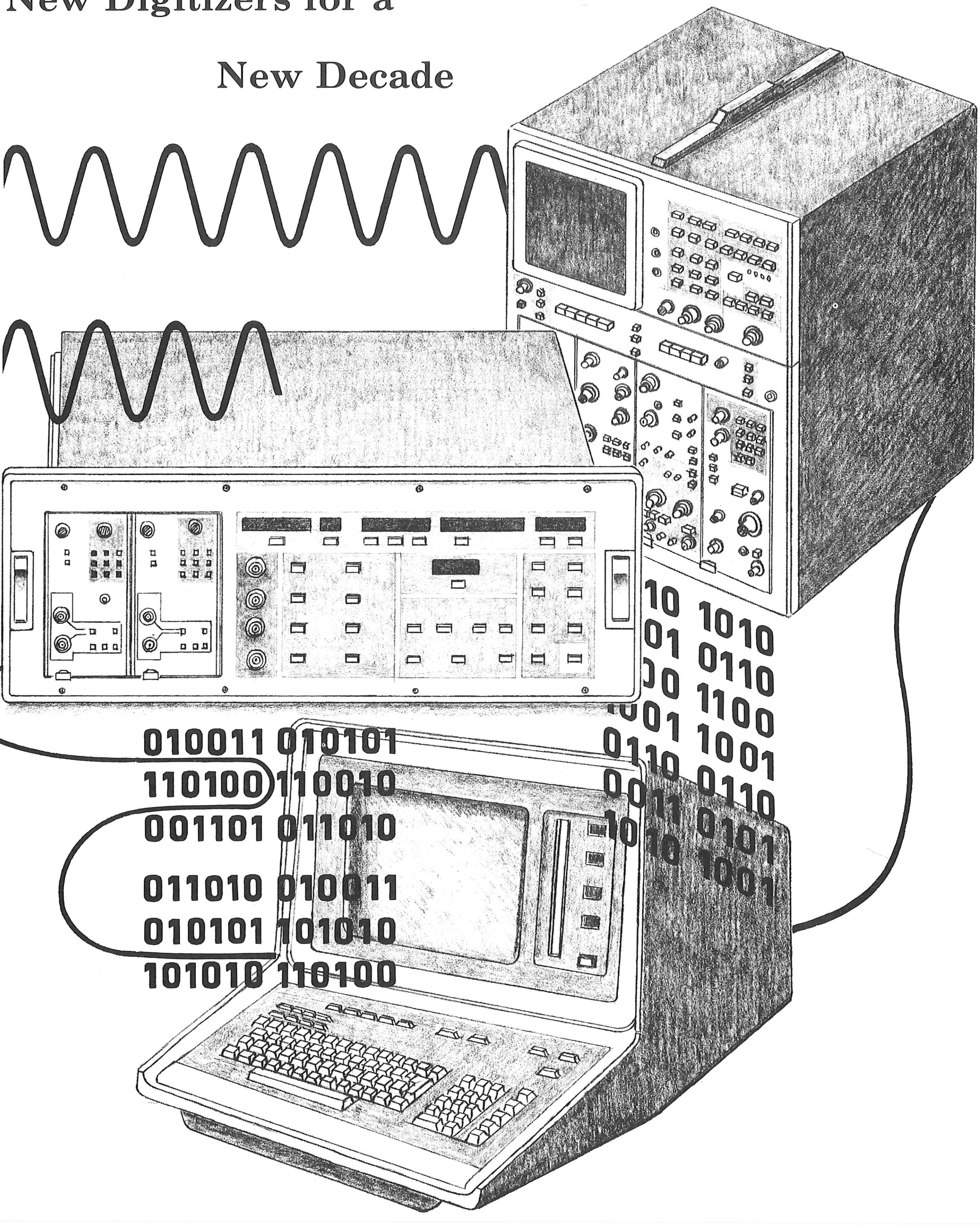
Tektronix®
COMMITTED TO EXCELLENCE

HANDSHAKE

Newsletter of the Programmable Instruments Users Group

New Digitizers for a New Decade



Tektronix COMMITTED TO EXCELLENCE | HANDSHAKE
Newsletter of the Programmable Instruments Users Group

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From R&D to QC...

With a multiplicity of new and exciting features—such as two independent channels, pretrigger, multiple record lengths, and sample rate switching within records—it's difficult to pick a beginning point for describing the 7612D. Perhaps as good a starting point as any is its full name.

Officially this new high-speed (200 MHz sequential sampling rate, 90 MHz bandwidth) instrument is called the 7612D Programmable Digitizer. And, as its name implies, it is fully programmable. Every instrument setting can be controlled by software over a General Purpose Interface Bus (GPIB). Of course, programmability and the GPIB aren't all that new. But they continue to be important to anyone facing the drudgery of repetitive measurements.

What is new, and more important in taming difficult waveforms, is that the 7612D Programmable Digitizer is a dual-channel waveform digitizer—a true dual-channel digitizer with a newly designed analog-to-digital converter for each channel and a crystal-controlled time base for each channel (see Fig. 1). Plus, each channel can be operated independently or dependently at whatever individual time base setting you like. Plus, because of sequential sampling and the 2048 words of partitionable memory provided for each channel, a variety of choices of how to digitize and of how to store each waveform become possible. As examples, you can:

- Capture simultaneous events with the two channels.
- Heighten definition of rapid signal transitions by adjusting sample interval during acquisition.
- Quickly capture and store up to eight successive events per channel by dividing memory.
- Avoid most common triggering problems by using pre- or post-triggering to shift waveform capture time to either side of the trigger point.

Since these features are designed to make short work of what have traditionally been the most difficult or sometimes impossible measurement situations, they bear some further examination.

Two channels, dozens of possibilities

Operated independently, the dual-channel feature of the 7612D Programmable Digitizer makes the instrument appear as two independent

New digitizer tames difficult waveforms

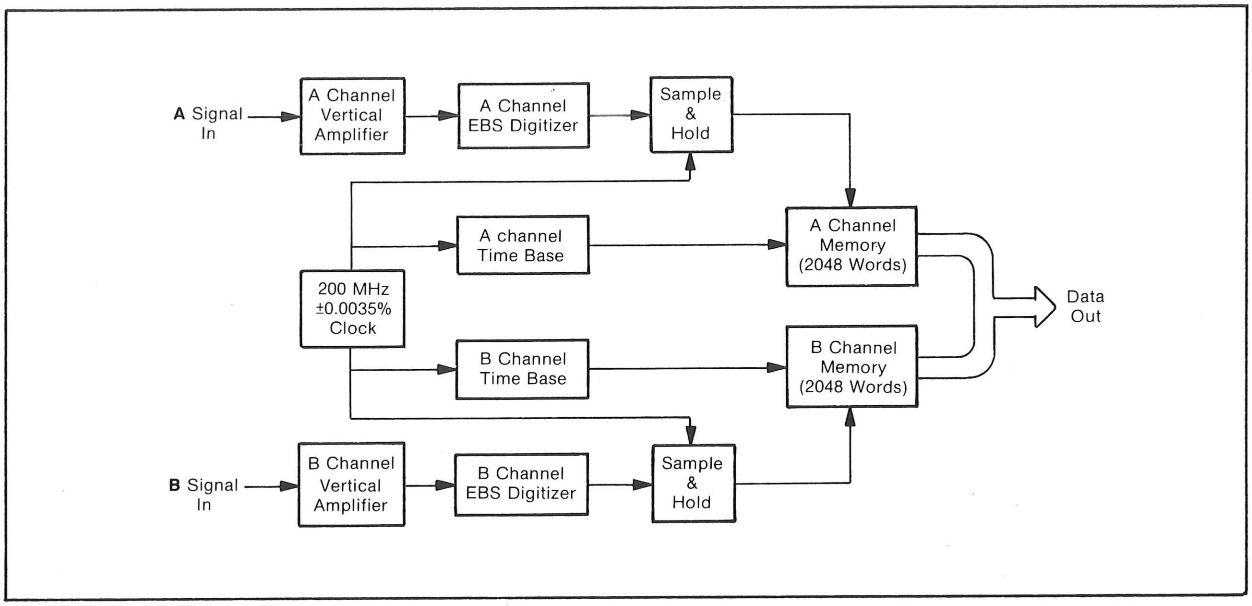

Fig. 1. *Diagram of 7612D dual-channel organization. Notice that the sample-and-hold operation follows the EBS (electron-bombarded semiconductor) digitizer. This nontraditional arrangement is part of the state-of-the-art approach of EBS digitizing where analog signals are fed to the digitizer and high-speed sampling is done later with digital comparators.*

waveform acquisition units. This is convenient when you need to deal with two different waveforms or measurements, but it is an absolute necessity if the two waveforms are one-of-a-kind and must be looked at simultaneously. Examples of the latter are capturing input-output information such as in transient response studies, other transient cause-and-effect relationships,

The EBS secret: How to digitizer faster, more accurately

Waveform digitizing today can be a bed of roses—a fragrant cushion of soft petals or a thorny pile of stems, depending upon what you want to do.

For example, putting digital power and accuracy behind standard oscilloscope measurements has been possible for quite some time. The TEKTRONIX Digital Processing Oscilloscope (DPO) can take you up to 150 MHz, and now the new 7854 Oscilloscope gives you a 400 MHz bandwidth for digitizing waveforms. You can even push these instruments into the GHz region with sampling plug-ins. A bed of roses...as long as you are dealing with repetitive waveforms.

But things can turn thorny for transient signals. You can still comfortably digitize low-speed single-shot phenomena with the psuedorandom techniques of the DPO or 7854. Even very fast transients, requiring up to one gigahertz bandwidth, can be captured and digitized with the scan-conversion technique used in the 7912AD Programmable Digitizer. It's the medium-speed transients that can be a thorn in the side. And they are a particularly sharp thorn when long records (1024 or more points) are necessary for time resolutions on decays or when pre- or post-trigger capabilities are needed. These capabilities can only be provided by high-speed sequential digitizing.

Semiconductor technology has been making strides toward higher frequency sequential digitizers on chips. Current offerings, however, have only reached the 8-bit 30 MHz mark, although faster chips are in experimental stages. Experimental components aside, the only way to push above 30 MHz for sequential real-time digitizing is with a flash converter.

Figure 1 (page 5) shows a typical flash converter layout. The concept is quite simple. Each

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and certain voltage breakdown phenomena such as illustrated in Fig. 2.

The two channels of the 7612D can also be operated dependently. For example, one can be triggered after the other to provide a higher sensitivity look at the beginning or ending of a waveform. Or, in another case of one triggered after the other, the full 4096 words of 7612D memory can be used to capture long-duration waveforms such as frequently occur in studies of transient shock and decay phenomena. Figure 3 illustrates both of these uses.

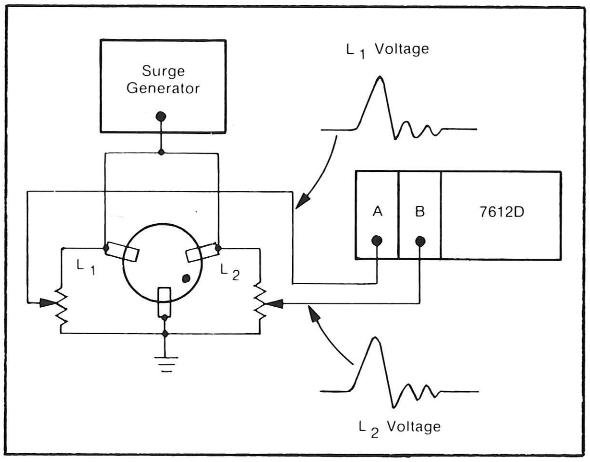

Fig. 2. *Dual-channel operation allows capture of simultaneous occurrences. In the above case, a 3-electrode gas lightning arrester with a common discharge chamber is being evaluated for simultaneous and equal breakdown.*

Multiple records conquer multiple waveforms

While each channel has available up to 2048 words of memory, it may not always be necessary or even desirable to use that full record length for storing a waveform. Consequently, the 7612D Programmable Digitizer has been designed to allow sectioning of each channel's memory into multiple records. You can have one 2048-word record, or up to two 1024-word records, or up to four 512-word records, or up to eight 256-word records for each channel.

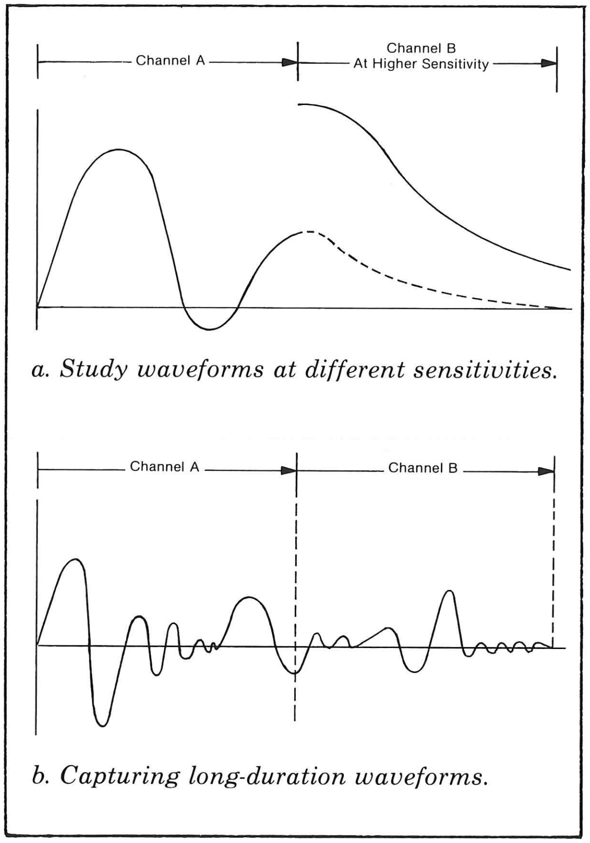

Fig. 3. *By triggering the B channel after the A channel, transient decays can be studied at greater sensitivity (a) or long-duration signals can be concatenated into the full 4096 words of available memory.*

When either channel is operated in a multiple-record mode, a trigger is required for digitizing into each record. However as each record is filled, the 7612D trigger circuitry is automatically rearmed. This way acquisition into the next record can begin as soon as a trigger is recognized. The result is that you can acquire a sequence of up to eight 256-point waveforms into each channel, or, if both channels are partitioned to their maximum, that means a total acquisition capability of sixteen 256-point waveforms.

This multiple-record capability with automatic trigger rearming allows you to capture rapid successive events such as indicated in Fig. 4. And, as an additional measure of flexibility, the sample-rate-switching and pre-trigger capabilities can also be used for each record.

Capture quick changes with sample rate switching

Not only can the sample rate be changed for each channel of data, but it can also be varied within records. This latter case is referred to as sample rate switching, and its effect is similar to

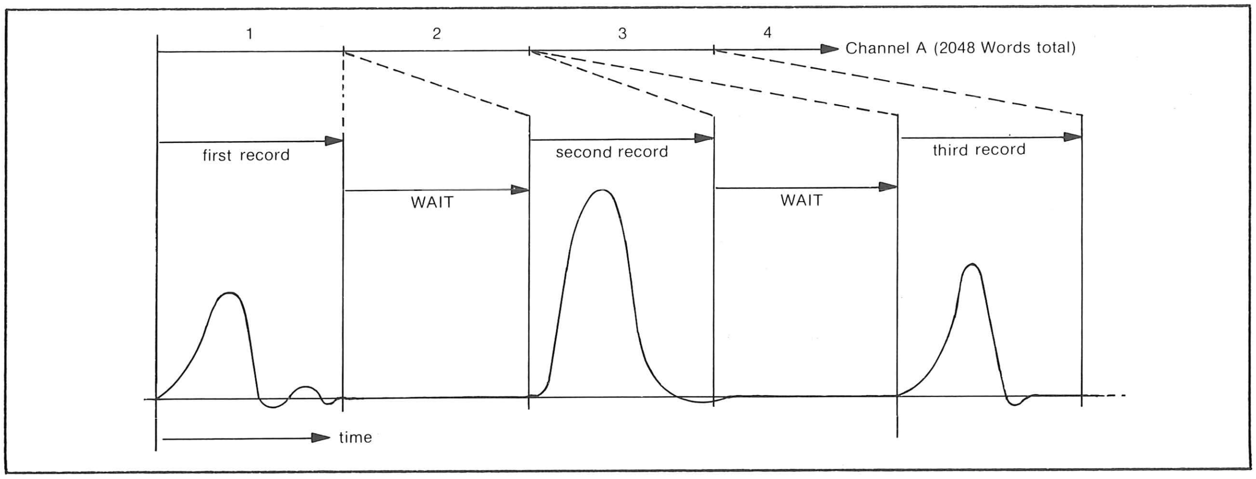

Fig. 4. *The multiple-record capability allows capture of a rapid succession of events. After capture, the up to eight waveforms allowed per channel can be transferred to an external device for either storage or complete parameter analysis.*

providing a stepped sweep on an oscilloscope or being able to switch sweep speeds during a sweep.

The capability of sample rate switching is a real boon when dealing with waveforms having fast transitions mixed with slower changing or stable segments. An example is shown in Fig. 5, where fast sampling allows fine definition of the pulse's rise and fall and slower sampling on the pulse top avoids amassing tremendous quantities of redundant data. The available sample intervals derived from the internal clock are selectable in 74 steps (1,2,3,...,9 sequence) from five nanoseconds

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The EBS secret...

comparator in the converter is referenced at an incrementally higher voltage through the precision resistor divider. On the other side, the converters are parallel fed by the signal to be digitized. The converters referenced above the signal level at any point in time remain off. Those referenced below the signal level are turned on, and the highest ON increment is converted to a binary output. It's a very fast technique of conversion, but for n bits of resolution it requires 2^n-1 comparators plus a very precise voltage divider. That is 255 comparators for an 8-bit flash converter—an expensive approach in terms of number of components, real estate, and number of calibration steps to trim each resistor in the divider.

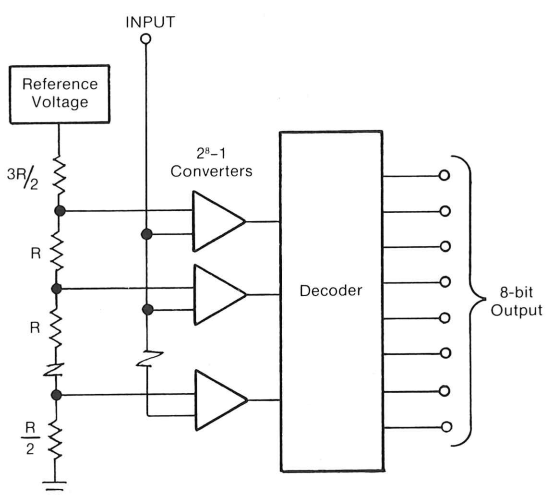


Fig. 1. *A typical flash converter circuit requires 2^n-1 comparators, where n is the desired bits of resolution. For 8 bits, that is 255 comparators.*

The EBS (Electron Bombarded Semiconductor) approach, by contrast, reduces the comparators to a number equal to the bits of digitizer resolution. For an 8-bit digitizer, there are 8 latching comparators as opposed to the 255 amplitude comparators required for traditional flash conversion. The EBS method still enjoys parallel input conversion speed but also uses the cathode ray tube techniques of the scan converter to achieve simplicity and accuracy. The EBS concept embodied by this combination of technologies is illustrated further in Fig. 2.

The EBS tube consists of various focusing rings and alignment plates that converge electrons from the electron gun into a flat ribbon beam. The signal to be digitized is applied to a set of vertical deflection plates that cause the ribbon beam to move up and down according to the applied signal

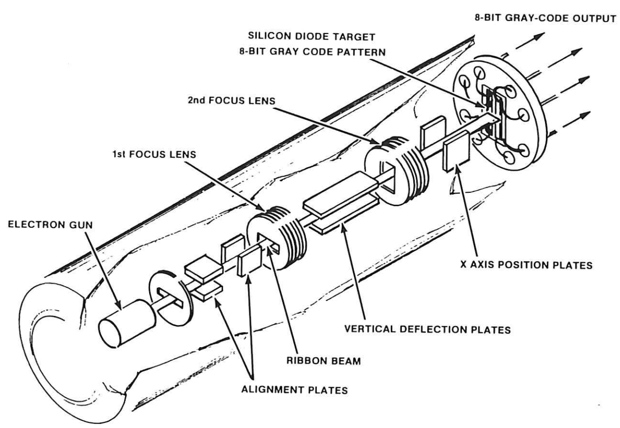
continued on page 6

amplitude. A diode target strip, which the beam is focused on, encodes the vertical position of the beam and thus the amplitude of the signal being digitized.

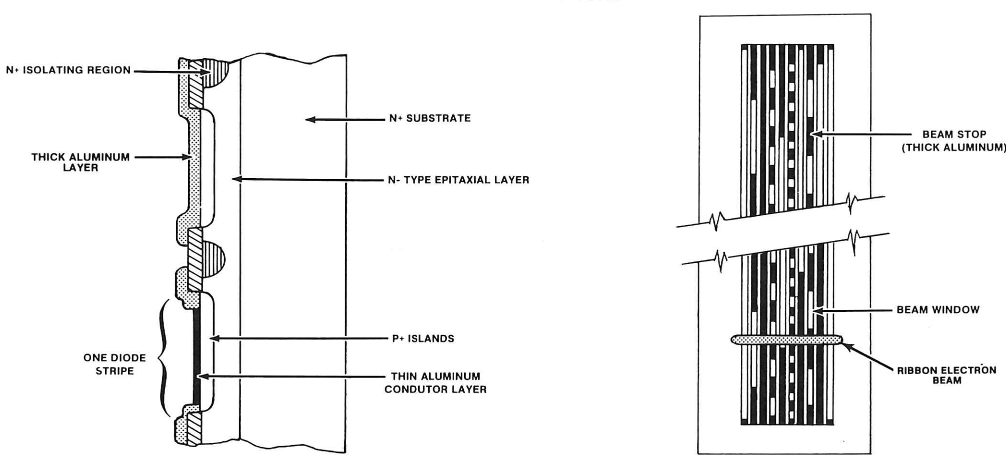
The diode target construction, also shown in Fig. 2, is such that there are 10 diode strips on the target. The two outer diode strips are unmasked over their lengths and serve as beam calibration guides. The inner eight diodes are masked over their lengths leaving only exposed ports or windows positioned to form a gray code indicating vertical position. Whenever the ribbon beam passes through a port, it causes the underlying diode to turn on. The vertical position of the ribbon beam on the target and the arrangement of ports result in the eight diode strips being on or off in a gray-code pattern that uniquely defines the beam position.

The on or off condition of each diode strip is detected by Tektronix designed high-speed comparators, one comparator for each strip. Since the least significant bit coming from the target can be changing at a rate in excess of 2 GHz, signal lead lengths become critical. To keep the leads short, the eight comparators are fastened directly to the outside of the EBS tube near the target. The digitized signal amplitude is clocked out of the tube-mounted comparators at a 5-nanosecond (200 MHz) rate.

Since electron beams can be accurately and rapidly deflected over short distances and diodes can be designed for very fast responses, the EBS technique realizes unprecedented speed in sequential, real-time digitizing. As for accuracy, it's inherent in the precision masking of semiconductor technology, the advanced state of cathode ray tube technology, and the requirement for only 8 comparator latches instead of 255 amplitude-calibrated comparators. That's the EBS secret—combining state-of-the-art technologies to solve the thorniest digitizing problems.



a. EBS tube construction.



b. Diode target details (target size: approximately 250 x 40 mils).

Fig. 2. *The EBS tube used in the 200-MHz, 8-bit 7612D Programmable Digitizer.*

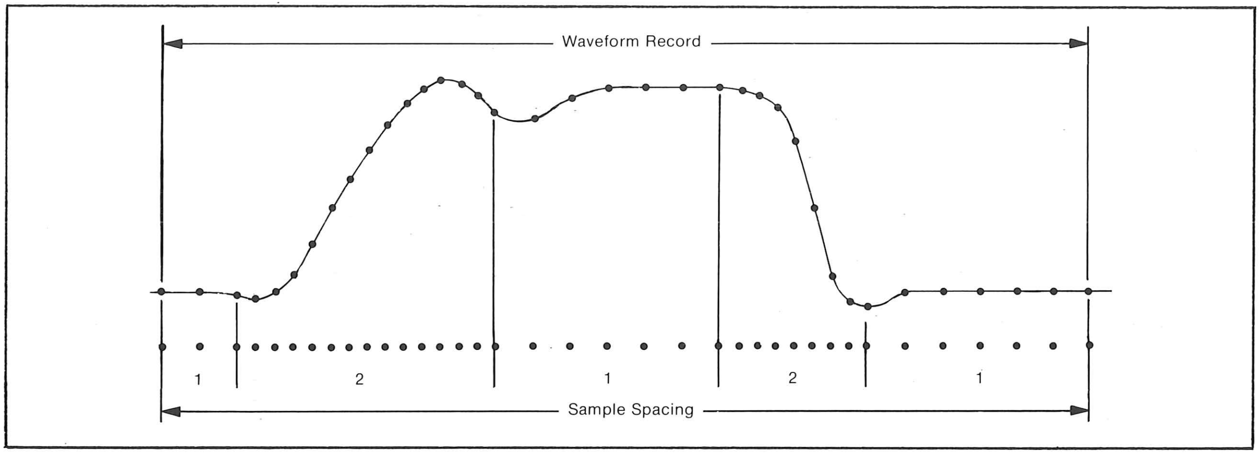


Fig. 5. *Sample rate switching during the waveform record can be used to increase time resolution on transitions. The above example shows switching between rates 1 and 2 with four rate changes during the record. Up to 13 sample rate changes are allowed during a waveform record.*

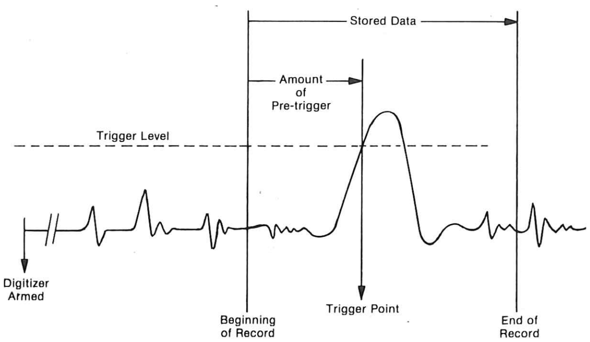
to one second. Switching intervals or sample rates can be done up to 13 times during a waveform record.

Pre- and post-trigger improve data choices

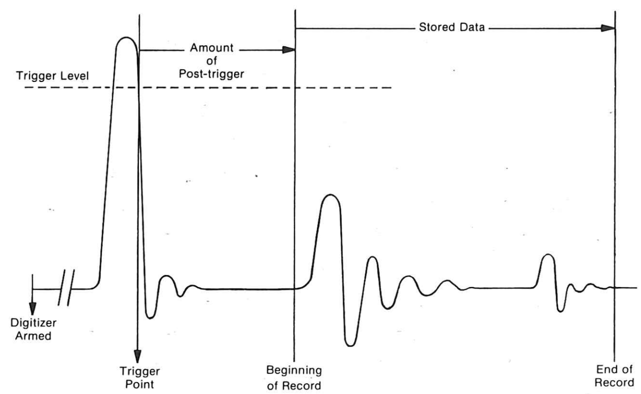
The pre-trigger and post-trigger features of the 7612D Programmable Digitizer allow you to effectively advance or delay waveform acquisition from the point of trigger. Either operation stems from the continuous, sequential sampling provided by the 7612D. Once the digitizer is armed, it begins digitizing samples sequentially and storing them in its first-in, first-out memory. New waveform samples are pushed into one end of the memory while the oldest samples are discarded as they are pushed out of the other end. This goes on until a trigger is received and implemented. Implementing the trigger causes the current set of waveform samples to be frozen in memory. The operations of pre-trigger and post-trigger are obtained simply by digitally advancing or delaying trigger implementation. The affects of this are shown in Fig. 6.

In Fig. 6a, the use of pre-trigger to get a stable trigger above base-level noise is illustrated. The trigger level is set high enough to obtain stable triggering on the waveform. At the same time, the pre-trigger time is set to include storing of a selected portion of data occurring before the trigger point. The result is that you can avoid noisy triggering and still get waveform data that includes the entire leading edge as well as data preceding the leading edge if you like.

Another use of pre-trigger is in the study of cause and effect. The effect might be the easiest or only thing to trigger on, in which case, pre-trigger lets you look back in time at the cause. Studying transient build ups associated with system power-on sequences is just one example of this.



a. Pre-trigger operation.



b. Post-trigger operation.

Fig. 6. *Pre- and post-trigger operation let you select just the segment of data you want.*

The opposite situation, post-trigger operation, is shown in Fig. 6b. In this case, fixing the stored data in memory doesn't occur until the selected post-trigger time has elapsed. This is useful for

From R&D TO QC...

acquiring data occurring some time after a triggering event—aftershocks or reverberations resulting from a test impulse, for one example.

Then of course there is standard triggering, too, where storage starts at the time of triggering. So you can move any way you like through time to get just the right data for your application.

And it's all programmable

The amount of pre- or post-trigger, sample interval and where it should be switched and by how much, record length and number of records, and triggering modes for independent or dependent dual-channel operation can all be set or selected either manually or under program control over the General Purpose Interface Bus (IEEE 488-1975). And, beyond these major features, all of the other mainframe settings (except power ON-OFF) can be controlled either manually or under program control. Add to this a pair of 7A16P Programmable Amplifiers for the vertical channels and the instrument becomes a totally programmable instrument.

Not only is the 7612D programmable in the sense that software can be used to change instrument settings, but it is also programmable in the sense that software can read or learn current instrument settings. You can work out a test sequence manually the first time while software learns and stores the settings. Then the next time the test is run, it can be run completely under software control, including setting up the instrument.

General instrument control routines can be written for exploring the unknown or uncertain in R&D. Or more specific routines can be written for quickly executing the repetitive operations common to QC applications. In either case, the 7612D Programmable Digitizer has the power and flexibility to freeze even the most unruly waveforms in memory. Add to this the signal processing power offered by TEK SPS BASIC software, and those waveforms can be analyzed in detail for whatever parameters your application demands.

By Bob Ramirez
HANDSHAKE Staff

Interactive 7612D acquisition routine

This bare-bones program was written by Mark Tilden, Tektronix SPS Documentation Group, to interactively control one 7612D via the TEK SPS BASIC low-level GPIB driver (GPI.SPS). In response to the program's prompt (**7612**>), you can ask for the content of the status byte or enter a single 7612D set or query command. The program also responds to an SRQ interrupt from the 7612D by reporting the content of the status byte. No checking is made to see if the input is correct or appropiate, so careless typing may cause an error. If an error is fatal, you should restart the program after sending the 7612D a device clear.

```
 10 LOAD "GPI
 20 SIFTO @0,6000
 30 PRINT "7612>";
 40 WHEN @0 HAS "SRQ" GOSUB 240
 50 INPREQ GOSUB 70
 60 GOTO 60
 70 INPUT C$
 80 IF C$="STAT?" THEN 210
 90 PUT C$ INTO @0,32,96
100 L=LEN(C$)
110 IF SEG(C$,L-5,L-2)="READ" THEN 160
120 IF SEG(C$,L,L)<>"?" THEN 270
130 GET A$ FROM @0,64,96
140 PRINT A$
150 GOTO 270
160 DELETE A
170 READBI A FROM @0,64,96
180 PAGE
190 GRAPH A
200 GOTO 270
210 GETSTA @0,ST,64,96
220 HPRINT "MAINFRAME STATUS (HEX): ";ST
230 GOTO 270
240 POLL @0,ST,PA,SA;64,96;64,97;64,98
250 PRINT "SRQ FROM ADDRESS :";PA;SA;
260 HPRINT " STATUS (HEX):";ST
270 PRINT "7612>";
280 RETURN
```

For expediency, the routine assumes the interface number, the primary address, and the secondary address are all zero. This means a primary listen address of 32, a primary talk address of 64, and a secondary address of 96 are used with the low-level driver.

The first six lines set up the program. The driver is loaded and the time-out value is set to six seconds, and then the prompt is printed. Next, an SRQ interrupt and an input request are set up. Finally, the program loops at line 60 until a line is entered from the keyboard or an SRQ is asserted. When either happens, control transfers to the subroutine which handles the 7612D command string or prints the status byte and prints the prompt when done. Then control returns to line 60 where the program continues to loop.

All input (except the string "STAT?") is simply

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Dynamic testing reveals overall digitizer performance

Typically, full bit resolution and fastest sampling rate are the first two characteristics given when real-time digitizer performance is mentioned. These two items head the specification list and, in fact, are important indicators for comparing the ideal performance of real-time digitizers. But, for actual performance in a particular application, a careful look has to be taken at some items further down on the specification sheet.

Further down on the list are such items as gain error, offset error, linearity, and monotonicity. Gain and offset errors manifest themselves as an incorrect signal amplitude and an incorrect DC component, respectively. However, instrument calibration can reduce these errors, and often what's left can be characterized and removed by either firmware or software routines. Linearity and monotonicity errors, on the other hand, cannot generally be calibrated out. Thus, they must be specified individually, or their effects must be considered or accounted for in some other specified parameter.

Still further down on the list, bandwidth might be specified. Unlike sampling rate, which tells you by the Nyquist criterion the highest frequency component ($f_N = f_S/2$) that can be digitized without aliasing errors, the bandwidth specification tells you at what frequency you can expect amplitude attenuation to begin increasing.

Of all the items on the list, which are most important in choosing a real-time waveform digitizer?

Current specifications only partial picture

All of the standard digitizer specifications are important to consider. But still it is difficult to combine their individual effects into something giving an accurate picture of overall waveform digitizer performance.

To further complicate the issue, there are other sources of error that can be digitizer dependent as well as dependent upon signal frequency or rate of change. Examples of these sources are aperture uncertainty and the response of the least-significant-bit comparators and associated circuitry. Often these error sources are not specified. So the user is left, at best, questioning just how accurately the digitizer performs across the frequency band, and at worst, believing that accuracy corresponding to full resolution is achieved no matter what the input frequency.

The question then arises: "How can all of these errors be taken into consideration when trying to assess actual digitizer performance?"

Efforts to answer this question have resulted in development of the "Dynamic Performance Test." This test is a computer-oriented black-box approach to testing the overall performance of most real-time analog-to-digital converters and waveform digitizers. Its main advantage is consolidation into a single specification most of the otherwise difficult-to-describe error sources.

Focusing on dynamic operation

Dynamic performance means, essentially, performance under a changing circumstance. In the case of a waveform digitizer, this means testing with a changing input signal, a sine wave for example. In particular, using a sine wave offers several advantages over other types of test signals. First, high-frequency sine waves can be generated with relative ease. And, second, sine waves are easily characterized.

These factors combine to make dynamic testing quite simple in concept. A high-quality sine wave is captured by the digitizer under test. In conjunction with this, an associated computer is used to generate an ideal sine wave matching the captured sine wave in amplitude, frequency, phase, and vertical position (including offset). Also, an ideally sampled and digitized version of the sine wave is generated by the computer. Then the actual digitizer output, the ideal sine wave, and the ideally sampled and digitized sine wave are compared in various ways, and some statistics are computed to reflect the accuracy of the digitizer's output.

That's the basic concept. The details are better revealed through a test example.

To begin, a high-quality sine wave generator is required. Its performance must exceed that of the digitizer under test so that inaccuracies in the digitizer's output cannot be attributed to the signal generator. In some cases, notch filters may be required at the generator's output to keep harmonics below what is expected from the digitizer.

The output of the sine wave generator is digitized by the instrument under test, and the result stored in the computer. Figure 1 shows an example of stored output from an 8-bit digitizer. Each of the 32 samples shown is an integer corresponding to a quantization level within the range of 0 to 255 (an 8-bit digitizer has $2^8 = 256$ possible levels with zero being the lowest level).

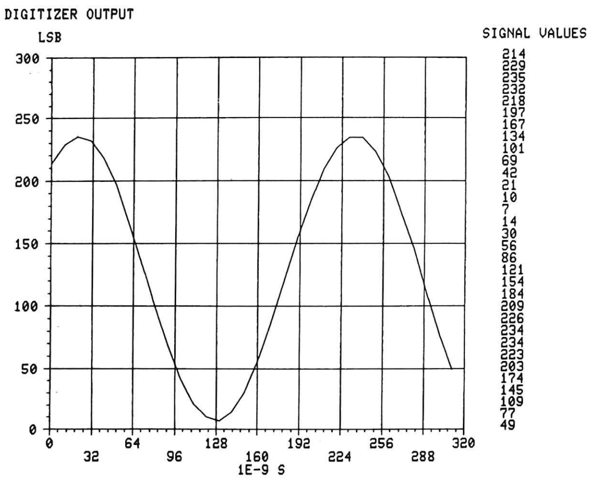


Fig. 1. *Stored data from a sine wave that has been sampled 32 times and digitized by an 8-bit digitizer.*

With the test sine wave digitized and stored, computer analysis can begin. The first step is to fit a perfect sine wave to the digitized signal. This perfect sine wave is fully described by

$$A \sin(2\pi ft + \Phi) + C$$

where A is amplitude, f is frequency, Φ is phase, t is time, and C is DC offset. Fitting this sine wave to the digitized signal is done by a software routine using a least squares method, and the result is considered to be a description of the analog input to the digitizer. It should be noted, however, that because the analog signal parameters are computed from the digitizer's output, DC offset and gain errors are not included. Therefore, tests for DC offset and gain error should be done separately.

Having computed the characteristics of the analog input from the digitizer's output, some statistics necessary to describe the digitizer's performance can be generated. To do this, the computed sine wave input is perfectly sampled by the computer at specified sampling times, t. Values resulting from this are shown in Fig. 2. These values are shown as noninteger values

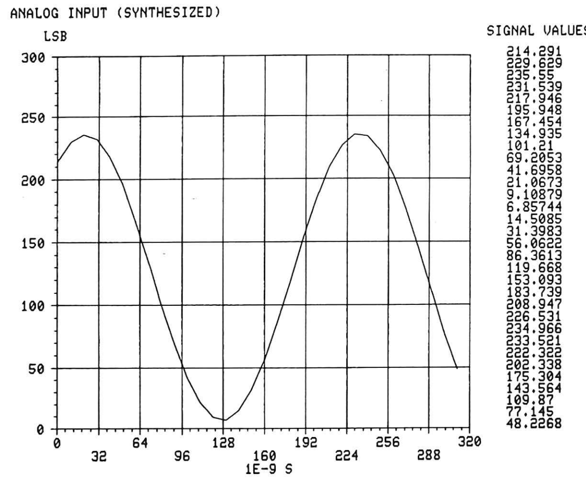


Fig. 2. *Ideal sine wave synthesized from output data of the digitizer under test and perfectly sampled at 32 points.*

since only sampling—not quantization—has taken place. Quantization is the next step undertaken by the computer. This is done by rounding the sampled values to the nearest digital level within the proper digitizing range. Figure 3 shows the effects of this perfect quantization. Notice that the values of the computed input signal are now integers within the range of 0 to 255. This (Fig. 3) is ideal digitization of the input signal, or, in other words, the output of a perfect 8-bit digitizer.

The difference between the perfectly sampled signal of Fig. 2 and the real digitizer's output (Fig. 1) represents the analog error signal for the digitizer under test. The difference between the perfectly sampled signal (Fig. 2) and the perfectly

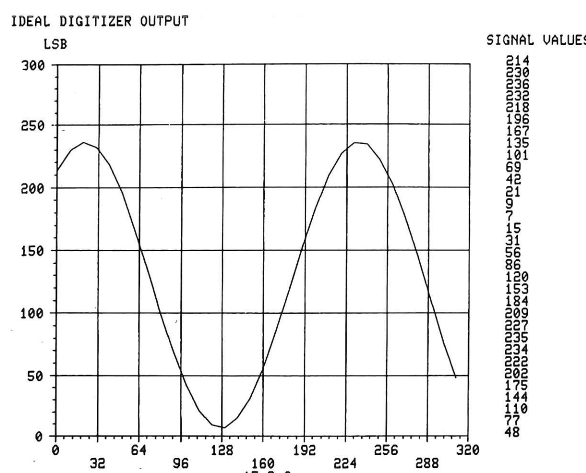


Fig. 3. *Synthesized sine wave after being perfectly quantized.*

quantized signal (Fig. 3) represents the analog error signal of the corresponding ideal digitizer. Graphs of these analog error signals for the sample test are shown in Fig. 4. Notice that the values for the errors of the ideal digitizer lie between ±0.5 least significant bits (LSB). This is what is expected for an ideal digitizer. The real digitizer's error values in Fig. 4, however, are greater than ±0.5 LSB. This indicates a loss of accuracy in the digitizing process.

Developing final results

Two important performance parameters can be computed from the information gathered thus far—the digitizer's signal-to-noise ratio and the number of effective bits of accuracy. The signal-to-noise ratio (SNR) is determined by the following formula:

$$\text{SNR} = 20 \log \frac{\text{RMS (analog signal)}}{\text{RMS (real digitizer errors)}}$$

The effective number of bits lost by the digitizer is given by:

$$\text{Lost Bits (LB)} = \log_2 \frac{\text{RMS (real digitizer errors)}}{\text{RMS (ideal digitizer errors)}}$$

Subtracting the lost bits from the total bits of resolution available yields the number of bits at which the digitizer is effectively operating. In the example used thus far, the digitizer's ideal resolution is 8 bits. So the number of effective bits is then:

$$\text{Effective Bits (EB)} = 8 - \text{LB}$$

Figure 5 illustrates these test results for the example. Besides SNR and effective bits, some

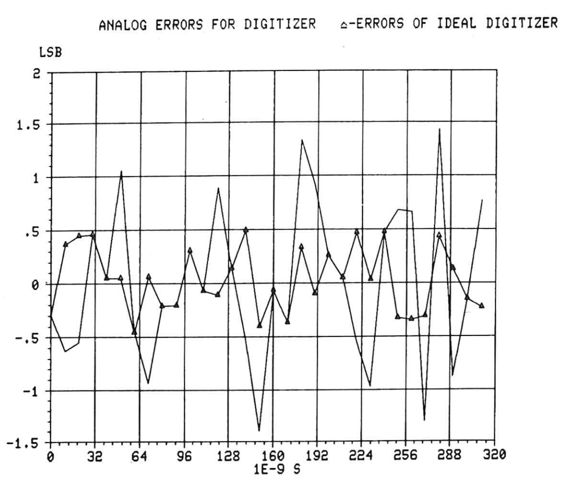


Fig. 4. *Example error signals associated with ideal and real 8-bit digitizing.*

```
I.D.  2-14-79 500OHM 4.7MHZ +1.5DB TBC/2
SIGNAL TYPE:  SINE
FILE NAME:  TST3

******** SUMMARY STATISTICS (IN LSB OR AS INDICATED) **

RMS OF DIGITIZER OUTPUT(DC REMOVED) =  79.3016

ANALOG ERRORS FOR DIGITIZER OUTPUT:
        MAX =  1.43629
        MIN = -1.39833
        RMS =  .721989

SIGNAL-TO-NOISE RATIO =  40.8147 DB

RMS ERROR FOR IDEAL DIGITIZER =  .297613

EFFECTIVE BITS =  6.72146
```

Fig. 5. *Output of dynamic performance routine.*

other potentially useful performance parameters are also displayed. These are the maximum, minimum, and RMS values for the errors from the digitizer under test and the RMS value of the errors from the synthesized ideal digitizer.

For the example test, Fig. 5 shows the number of bits at which the digitizer was effectively digitizing the 4.7 MHz sine wave to be 6.72146 bits. This means that for the sine wave the 8-bit digitizer was actually operating equivalent to an ideal 6.72146-bit digitizer.

As indicated earlier, this performance degrades as frequency increases. In fact, to get an accurate picture of the digitizer's response, tests at several frequencies should be conducted. The data from this can then be used to construct a graph, such as shown in Fig. 6, for either effective bits or signal-to-noise ratio.

Before testing at several frequencies, however, it should be pointed out that performance is also affected by the amplitude of the test sine wave. Several errors, including aperture error, can arise from the rate of change of the sine wave. This rate of change (dv/dt) depends upon both the frequency and amplitude of the test signal as can be seen from the following relationship:

$$dv/dt = d(A \sin(2\pi ft))/dt = A \cos(2\pi ft)$$

So it is important to keep the sine wave amplitude constant while running a series of tests at various frequencies.

Exactly what amplitude should be used in testing is another subject of discussion. It might be desirable to use an amplitude corresponding to the full resolution of the digitizer. Doing this,

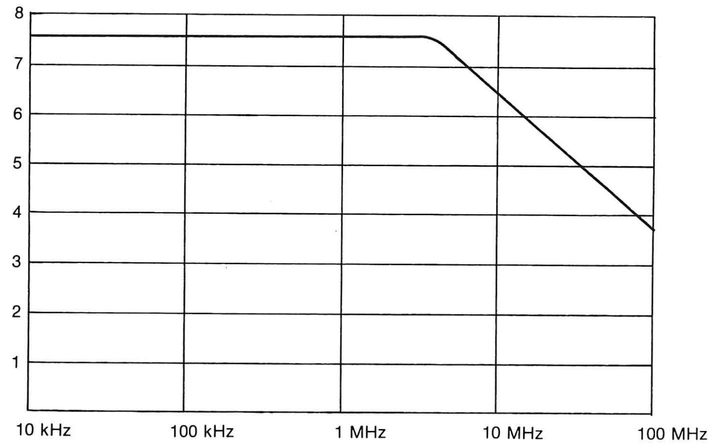


Fig. 6. *Plot of dynamic accuracy constructed from sine wave tests at several frequencies.*

however, forces the digitizer to handle the maximum dv/dt for any given frequency. This may not be a really fair test since most waveform digitizers are not typically used in modes where the acquired signal covers the full input scale. In practice, waveforms are more often acquired at less than full scale, so something like a half-scale amplitude sine wave would probably give a better picture of what digitizer performance will be in actual practice.

In fact, the 8-bit TEKTRONIX 7612D Programmable Digitizer has been characterized in this half-scale sine wave manner. The results are listed in the instrument specifications under "Dynamic Accuracy for Digitizing and Storage" and appear as follows:

Sine Wave Freq.	SNR	Effective Bits
300 kHz	42 dB	7.8
20 MHz	32 dB	6.0
80 MHz	20 dB	4.0

A better overall picture

With dynamic accuracy specified at enough points, it is possible to construct a graph (such as Fig. 6) and perceive expected digitizer performance in the frequency range of interest. Most error sources (except gain and offset) are accounted for in a few easy-to-understand, easy-to-visualize numbers. There is no longer any need to agonize over combining diverse error figures in an attempt to come up with an overall figure of performance. Indeed, most traditional waveform digitizer specifications become necessary only as a matter of general interest, while dynamic accuracy becomes the primary criterion of performance.

By Laurie DeWitt, Tektronix, Inc.
SPS Signal Analysis Group

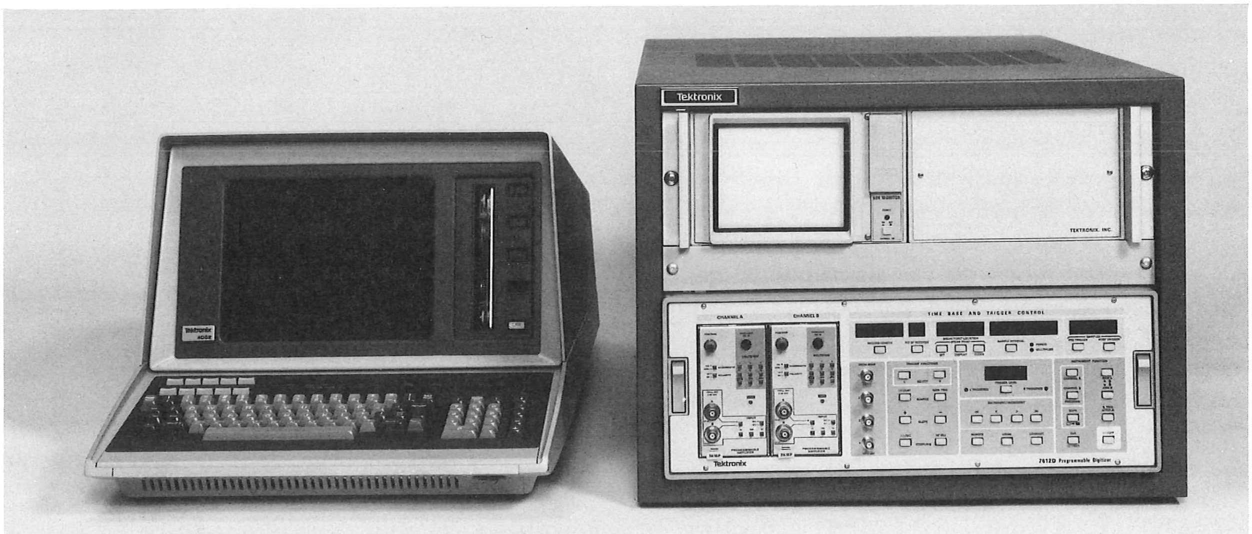
7612D acquisition routine...

sent to the 7612D with a PUT statement (line 90). If the entry ends with a question mark, it is assumed to be a query command; so, the response from the 7612D is read into a string variable with a GET statement and printed (lines 30 and 40). If the input does not end in a question mark, it is assumed to be a set command and no further action is taken unless it is a READ. In this case, a single channel of data is read and graphed (lines 160 to 190). No provision is made to handle the ALTernate or REPeat commands or to READ both channels.

If the input is "STAT?", the status byte of the 7612D is read and printed in hexidecimal (lines 210 and 220). Similarly, when an SRQ interrupt occurs, the status byte is read and printed (lines 240 and 250). If you do not have the High-Level Support package, change the HPRINT statements to PRINT statements.

Joyce Ferriss,
HANDSHAKE Staff

Configuring the 7612D for measurement solutions



The WP3110—desk-top economy with minicomputer performance.

Crystal-accurate, dual-channel digitizing to 100 megahertz. Pre-trigger, post-trigger, sample rate switching, and memory partitioning. The 7612D has them all...all of the capabilities necessary for quick, efficient, and complete waveform capture.

Plus, the 7612D is GPIB compatible and fully programmable. Interface it with a computer, and you have a system powerful enough to smash through any measurement bottleneck.

But wait! Before you pick just any GPIB controller for your 7612D, consider these questions:

- Does the computer have enough memory for two, three... maybe four or more waveform arrays of 2 K-words each?
- Is the data transfer speed adequate?
- Can the system handle arrays...integrate them, differentiate them, fast Fourier transform them?
- What about graphics and hard copy output?
- And what about the experience and expertise necessary for successful system integration?

If you don't have the right answers for these questions, then there's a good chance you'll be missing some important system benefits offered by the 7612D Programmable Digitizer.

A quick, cost-effective way to get the right answers is to look at the WP3000-Series of TEKTRONIX Signal Processing Systems. These fully integrated systems are assembled, tested, and completely documented to give you ready-to-go service from your 7612D Programmable Digitizer.

Desk-top computer-based system

The economical WP3110 is a pairing of the 7612D with the recently introduced TEKTRONIX 4052 Graphic Computing System. The 4052 is one of the most powerful desk-top computers currently available. Its bit-slice technology challenges minicomputer speeds, and its 64 K-word memory is quite capable of handling the large waveform arrays sent by the 7612D.

Easily programmed in an extended BASIC language, the 4052 offers complete signal acquisition, processing, and display capabilities. Measurement results appear before you in a matter of seconds. Plus, your computational power can be extended over what's available in more conventional desk-top systems by specialized ROM Packs. These ROM Packs both simplify and speed the execution of commonly encountered array processing functions. Things like integration, differentiation, and searches for array maximum and minimum values are carried out by calling single commands. Even the fast Fourier transform is available as a single comand that executes at minicomputer speeds.

Added to these standard processing tools are a variety of already written programs. As a 4052 user, you have access to the PLOT 50 software library, a collection of statistics, mathematics, and graphics programs that are applications oriented. Plus, you automatically become a member of the 4050 Users Club with access to applications software written by other members. Your specific applications program may already be there for the asking!

And once you've run your program, you'll have the advantage of high-resolution 4052 graphics and alphanumeric display. Special graphic routines help you quickly format results to meet your particular needs. Add a 4631 Hard Copy Unit or 4662 Digital Plotter, and your high-resolution displays can be transferred to paper for clearer, more concise scientific reports or quality control documents.

Minicomputer-based system

The WP3201, a pairing of the 7612D with a DEC PDP-11/34 minicomputer, is at the other end of the waveform processing spectrum. When speed and the amount of information to be handled are primary considerations, the WP3201 offers premium performance.

Based on Digital Equipment Corporation's reputable PDP-11/34, the WP3201 offers 128K words of minicomputer memory, two high-capacity disk drives (5 Megabytes each), a graphic terminal, and the field-proven TEK SPS BASIC language with extended memory capabilities for handling the large arrays coming from your 7612D Programmable Digitizer.

TEK SPS BASIC software is like no other software you've seen. It's system software...it's instrument control software...it's signal processing software...it's ready-to-use software.

Designed from an instrument and measurement background, TEK SPS BASIC is aimed at solving measurement problems quickly and completely, with a maximum of ease. The GRAPH command, for example, causes a complete waveform with axes and scale factors to be displayed on the graphic terminal. Complete waveform graphics with a single command!

And there are single commands for many other operations—integration, differentiation, fast Fourier transformation, and many, many more. Plus there are GPIB drivers to ease the burden of instrument control, whether you are using one instrument or a busful.

The fast GPIB driver allows acquisition of 7612D waveforms in times expressed in tens of milliseconds. And, with the new DLOG command, one hundred 256-point waveform arrays per second can be logged from a 7612D onto the peripheral disks. These powerful disk peripherals not only allow rapid mass waveform and program storage, but they allow almost instantaneous recall of either data or programs for further processing or display. Display is via a graphic terminal and is implemented through the complete and highly flexible TEK SPS BASIC graphics package. This allows quick and easy formatting of measurement results, and, by adding a 4631 Hard Copy Unit, the display can be transferred to paper for permanent records and reports.

The WP3201—for when speed and memory are of the essence.

All of this comes assembled and ready to run with on-site installation and system checkout provided as part of the WP3201 package.

The final question

All of the system questions about adequate memory, data transfer, array processing, graphics, and system integration are answered by the WP3110 and WP3201 systems. This leaves you with the final question: "Which system is best for my needs?"

To help you answer that question, Tektronix maintains a staff of experienced systems specialists in the field. They'll be able to work with you in assessing your measurement needs and choosing the system that is right for meeting those needs. To get in touch with your systems specialist, contact your local Tektronix Field Office. Outside of the United States, contact the Tektronix subsidiary or distributor in your country.

By Jean-Claude Balland,
SPS Marketing Program Manager,
Tektronix, Inc.

WP1310 backs 400 MHz oscilloscope measurements with computing power

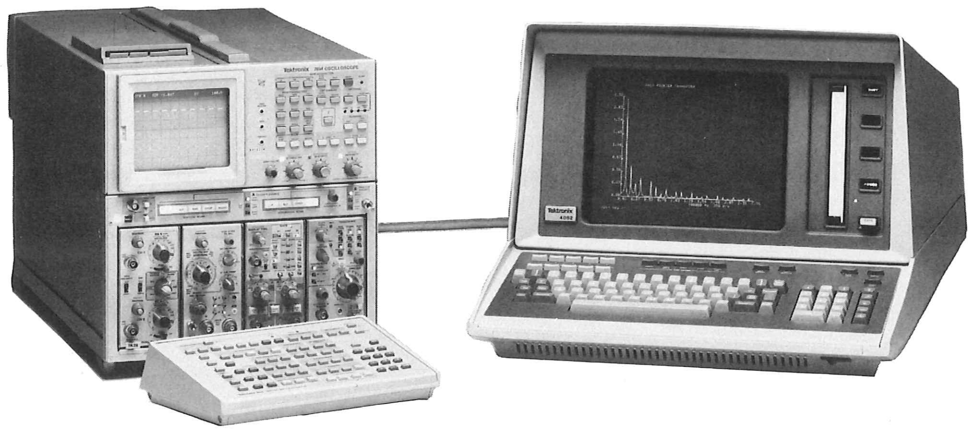


Fig. 1. *The TEKTRONIX WP1310 interfaces the 7854 Oscilloscope with the 4052 Graphic Computing System for a combination of modern digital oscillography with BASIC language waveform processing and graphics capabilities.*

Oscilloscope measurements with a new level of flexibility and power—that's the purpose of the WP1310 Waveform Processing System shown in Fig. 1. This new system uses the IEEE 488 bus to tie desk-top computing power to the recently developed 7854 Oscilloscope. The result is a new measurement tool offering you anything from standard oscilloscope measurements, through push-button measurement of pulse parameters, to programmed waveform analyses including operations such as fast Fourier transformations, convolution, and correlation.

Putting power into oscilloscope measurements

The system drawing in Fig. 2 points out some of the many WP1310 features. It also identifies the major system components, an acquisition unit (7854 Oscilloscope) and a system controller (4052 Graphic Computing System).

Basically, system operation begins with the acquisition unit, the 7854 Oscilloscope. This 400 MHz oscilloscope is not like your usual oscilloscope. Although it can be operated just like an oscilloscope, the WP1310 acquisition unit also contains a waveform digitizer, memory for storing digitized waveforms, and microprocessor power for some standard waveform calculations. As part of the WP1310 system, its function is to capture and digitize your waveforms, speedily preprocess them when necessary, and hand them to the WP1310 system controller for further analysis.

The WP1310 system controller provides high-speed processing as well as instrument control under BASIC language programs. Additionally, with the Signal Processing ROM Packs installed, the WP1310 system controller extends your selection of waveform analysis tools to include such things as

- Data windowing
- Fast Fourier transformation (FFT)
- Inverse Fourier transformation (IFT)
- Auto- and cross-correlation
- Convolution

Plus, the high-resolution graphics capability of the WP1310 allows formatting of results to your specific application needs. Would you like

- Bode plots

WP1310 backs 400 MHz oscilloscope...

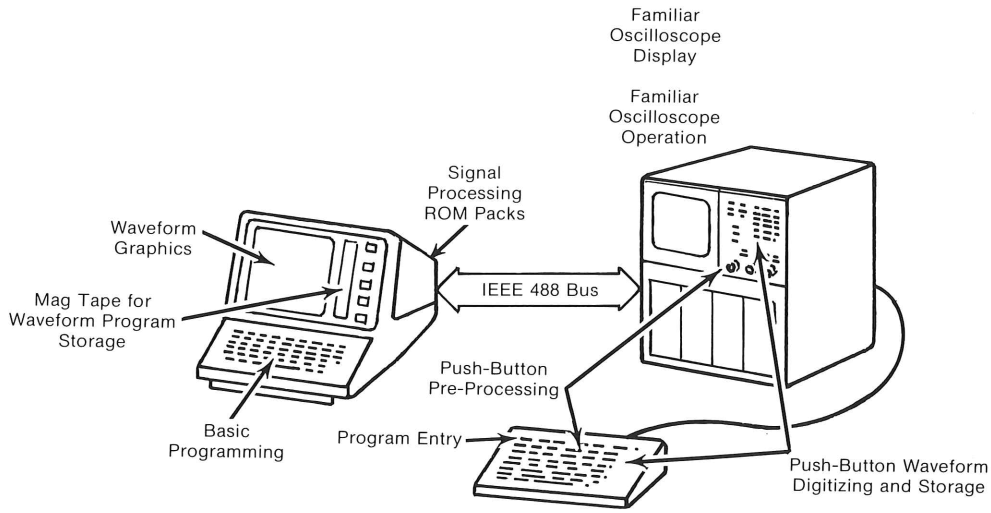


Fig. 2. *The WP1310 system components have a variety of features that combine for maximum benefits in waveform acquisition, processing, and storage.*

- Log and log-log displays
- Displays of system operating instructions
- Program listings and hard-copy capabilities

You can have them with the WP1310 system.

And there's still more. The WP1310 acquisition unit recognizes commands for changing the vertical and horizontal modes of mainframe operation. For example, you can send commands from the WP1310 controller over the bus to switch the acquisition unit from left vertical plug-in to right vertical plug-in. This allows you to have two different tests set up, one for each acquisition unit plug-in set, and to switch between them.

Of course the programs for doing these more complex processing and instrument control tasks can become lengthy. However, the WP1310 system controller has memory capabilities of up to 64 kilobytes with option 24. So there is plenty of room for program and waveform storage in the controller. Also, the WP1310 system controller has a tape drive which gives you access to an additional 300 kilobytes of magnetic tape storage. This latter feature is particularly important for permanent waveform and program storage since the WP1310 acquisition unit has volatile memory (the memory contents are lost if power is interrupted). The controller's magnetic tape will keep your data and programs secure.

Oscilloscope simplicity, digital resolution

With the WP1310, you set up for waveform measurements just like you would with a general-purpose laboratory oscilloscope. But then, instead of looking at the CRT display of the waveform and counting divisions to measure time or amplitude, press one of the acquire buttons (AQR for repetitive signals or AQS for single shot). This causes the acquisition unit to digitize the waveform supplied to its input and store the amplitude values in memory. Once in digital memory, a variety of high-resolution waveform measurements can be made quickly, easily, and automatically—often by pressing a single button on the instrument. The instrument does the division counting and scaling for you. And it does it quite well.

Because of the acquisition unit's 10-bit digitizer, vertical waveform values can be resolved to 1 part in 1024. Or in terms of a waveform display, that means you'll have the ability to detect amplitude differences as small as 0.01 division (based on a full scale of five vertical divisions above and below the center line). That's vertical resolution!

For horizontal or time resolution, you have a number of choices. You can digitize at 128, 256, 512, or 1024 points equally spaced in time on the waveform. With 1024 points selected and using the fastest calibrated time-base sweep of 0.5 nanoseconds per division, you can detect time differences as small as five picoseconds. Or, for really fast requirements such as evaluating optical fibers, a 7S12 Sampler plug-in can be used with the acquisition unit. With the 7S12 at its fastest rate of 20 picoseconds per division and using 1024 points, the sample interval then becomes 0.2 picoseconds.

The only requirement for such high degrees of time resolution is that the acquired waveform be repetitive. This is necessary for the asynchronous sampling (equivalent-time sampling) of the acquisition unit to build up a full complement of 1024 amplitude samples over several horizontal sweeps.

Since sampling is asynchronous at a 3.5 microsecond rate, the emphasis of the WP1310 system is on acquiring repetitive waveforms. However, provisions have also been added for sequential sampling of low-speed transients. This provision is made via the internal clock of a 7B87 time base. The 7B87 clock is used to gate sequential real-time sampling when the AQS (acquire single sweep) button on the acquisition unit is used for waveform acquisition. In this single-sweep mode, full sequential sampling (128, 256, 512, or 1024 points) with a minimum sample interval of about four microseconds can be obtained. Or, with an external clock, it is possible to obtain a two-microsecond sample interval. And, as a further benefit of sequential real-time sampling, pre-triggering becomes possible (see Fig. 3).

Digitizing in either the repetitive or single-sweep mode is accompanied by storage of the digitial waveform values and vertical and horizontal scale factors in the acquisition unit's memory. With the full memory option (option 2D), there are eight kilowords available in the acquisition unit for storing waveforms, constants, and analysis programs. The number of waveforms that can be stored varies according to the points per waveform. In the eight kilowords, space is provided for storing five 1024-point waveforms, or ten 512-point waveforms, or twenty 256-point waveforms, or forty 128-point waveforms.

Once in memory, any of the waveforms can be called up again, along with its scale factor information, for display on the acquisition unit's CRT. Up to nine waveforms can be displayed at one time. Also provided along with waveform storage in the eight-kiloword memory option is room for 100 constant registers and 2000 program elements (line numbers or commands). These storage areas can also be accessed for display on the acquisition unit's CRT.

Front-end processing power

Beyond just containing a waveform digitizer

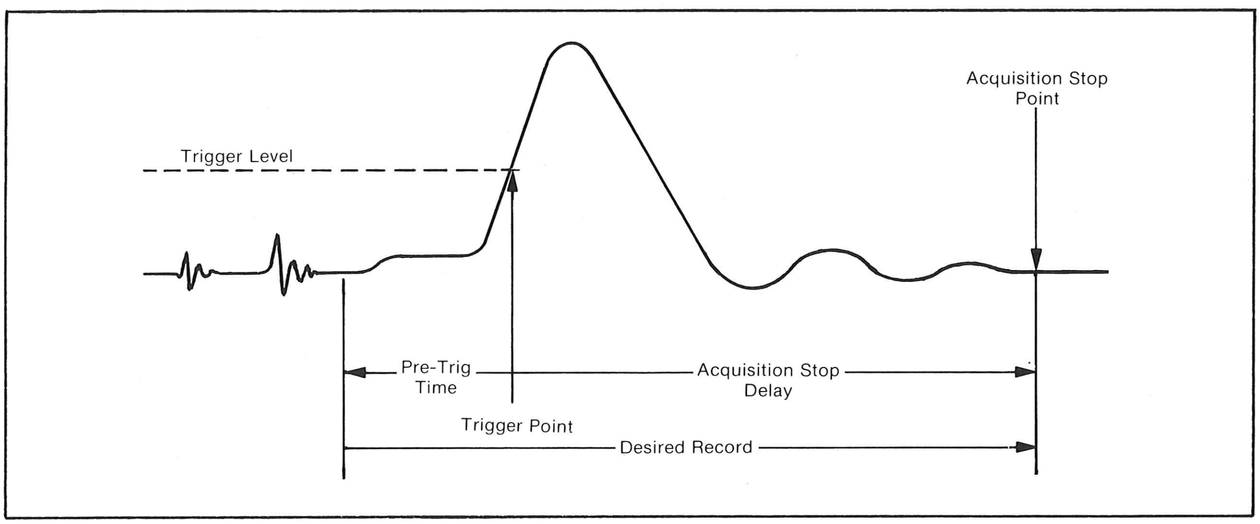


Fig. 3. *Pre-trigger: Unlike the repetitive mode where pseudorandom digitizing begins with the sweep trigger, the single-sweep acquisition mode using the 7B87 time base digitizes sequentially and continuously feeds samples to memory. This goes on until an "Acquisition Stop" freezes the most current samples in memory. By properly adjusting the "Acquisition Stop Delay" of the 7B87, those current samples can be made to include waveform data preceding the set trigger point. One benefit of this is that trigger levels can be set far above noise while still allowing capture of an entire leading edge in the pre-trigger zone.*

WP1310 backs 400 MHz oscilloscope...

and memory for waveform storage, the WP1310 acquisition unit also has an internal microprocessor with firmware for controlling waveform acquisition and processing. Push buttons on the front panel and the Waveform Calculator keypad put a variety of measurement processes at your fingertips.

- Waveforms can be captured with signal averaging to improve signal-to-noise ratio (AVG).
- A variety of general parameters can be computed from stored waveforms (MAX, MIN, P-P, MEAN, MID, ENERGY, AREA and frequency or period).
- Pulse parameters can be determined (FALL, RISE, DELAY, WIDTH).
- And a variety of other computations and manipulations can be made.

All by simply pressing buttons, just like a calculator and the results are conveniently displayed on the oscilloscope CRT (Fig. 4).

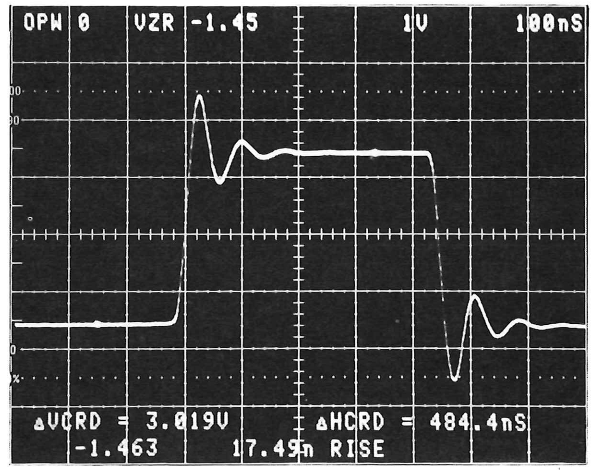
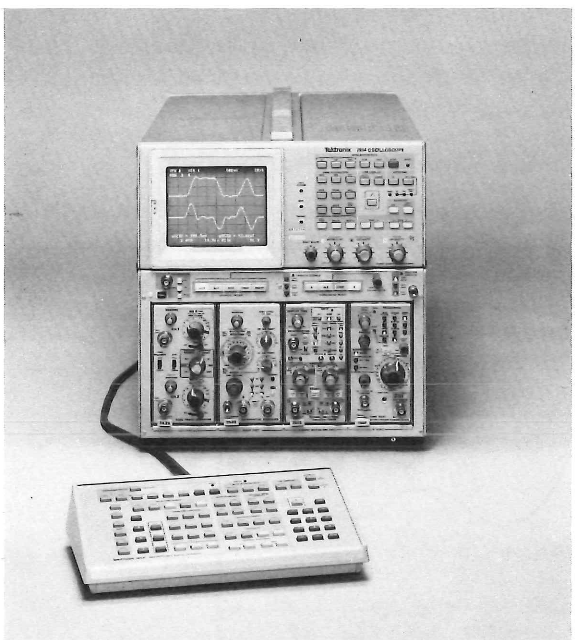


Fig. 4. *Stored waveforms can be recalled from WP1310 memory for redisplay at any time in a familiar oscilloscope fashion. Also, the displays are augmented by labels and waveform parameters computed by firmware.*

The 7854 Oscilloscope, a closer look



The acquisition unit of the WP1310 Waveform Processing System is the new TEKTRONIX 7854 Oscilloscope. Based on the Tektronix line of high-performance 7000-Series oscilloscopes, the new 7854 Oscilloscope takes a significant step beyond standard oscilloscope capabilities. Waveforms acquired through its 400 MHz bandwidth mainframe can be viewed in real time or digitized in equivalent time and stored in digital memory for later viewing and analysis.

Waveform analysis is provided in the 7854 through visible screen cursors and push buttons that invoke internal microprocessor routines for computing a variety of waveform parameters and mathematical functions. There are buttons for:

Delay time	Smooth
Pulse width	Integrate
Rise time	Differentiate
Fall time	Interpolate
Period	Recall ordinate
Frequency	Change ordinate
Maximum	Square root
Minimum	Natural log
Vertical midpoint	Exponential
Root mean square	Absolute value
Average value	Signum— +1, 0, or -1
Area under curve	+, -, *, /
Energy	., 0-9, and EEX

These are some of the more important function keys. Plus, there are additional keys for program entry, program execution control, and waveform acquisition, positioning, display, and expansion. And there are still more capabilities and features—including GPIB (IEEE 488) compatibility.

For a complete description of the 7854 Oscilloscope, contact your local Tektronix Field Office. Or request WP1310 information, which includes a 7854 Oscilloscope data sheet, via the reply card bound into this issue of HANDSHAKE.

Being able to make a measurement at the touch of a button is a great time saver. Counting squares, multiplying by scale factors, and other finger, visual, mental, and graphic gymnastics are reduced or completely avoided. Minutes are saved on simple measurements. Hours can be saved on more complex operations.

Additionally, multi-stepped measurement sequences can be programmed from the Waveform Calculator keypad, stored in the acquisition unit's memory, and recalled for execution. This means that even more time can be saved. Instead of re-pushing many buttons in sequence to perform each iteration of an analysis series, the buttons can be pushed once in the PROGRAM ENTRY mode. Then the entire sequence can be run automatically, as often as you like, in the EXECUTE mode. Not only does the button sequence run faster as a program, but measurement errors associated with manually executed sequences are dramatically reduced. Programs execute button functions the same every time—they don't forget steps or inadvertantly execute button functions out of the established sequence. That means a dramatic increase in measurement repeatability.

IEEE 488 compatibility

Once a waveform has been acquired and pre-processed by the WP1310 acquisition unit, it can be transferred to the WP1310 system controller for high-level processing. The transfer is over an IEEE 488 bus.

The same bus, because of IEEE 488 compatibility, can be used to tie more acquisition units into the WP1310 Waveform Processing System. You could have the WP1310 controlling up to 14 acquisition units in a multiple station test area for example. The programs could be down loaded to each acquisition unit according to the test needs at each station. With the WP1310 processing distributed between the system controller and the acquisition unit...well, you have just the measurement power you need when you need it and where you need it.

By Bob Ramirez
HANDSHAKE Staff

New TEK SPS BASIC releases offer more capabilities, more memory

Two new releases of TEK SPS BASIC software, V02-02 and V02XM-02, are now available for updating your signal processing system. Both releases retain the previous capabilities of TEK SPS BASIC as well as offer the additional capabilities of

- A high-level GPIB driver
- Support for additional peripherals
- Additional programming convenience
- A 7612D commands package

And, beyond these features, V02XM-02 offers extended memory for handling large waveform arrays such as those that can come from the new 7612D Programmable Digitizer or many smaller arrays such as might come from any other digitizer.

The importance of these new capabilities becomes apparent in taking a closer look at each of them. For owners of the new 7612D Programmable Digitizer, the 7612D commands package and the extended memory version will be of particular interest.

High-level GPIB driver

The low-level GPIB driver is still a part of the TEK SPS BASIC monitor. And it still offers the greatest flexibility in dealing with a wide variety of interpretations and implementations of the GPIB standard.

The new high-level GPIB driver, however, can make life a lot easier when dealing with certin standardized data transfers over the GPIB. It reduces the number of program lines necessary for communicating with many GPIB instruments, and the commands are simpler and easier to remember. With the high-level GPIB driver, a single command is all that is necessary now to acquire data from either the 7612D or 7912AD Programmable Digitizers.

New TEK BASIC releases...

Additional peripheral support

If you would like to add either an RL01 disk drive or an RX02 double-density floppy disk drive to your system, the new releases of TEK SPS BASIC software have been augmented to support these devices. This is in addition to the original line of peripherals supported by the previous software releases.

Also, both new releases have an enhanced graphics keyboard driver. This lets you exploit the higher resolution of TEKTRONIX 4014 Computer Display Terminals fitted with the Enhanced Graphics Module option. With the enhanced graphics, your signal processing data can be automatically displayed with the resolution of a 0-3114 Y and 0-4095 X coordinate system. And you won't have to modify your existing TEK SPS BASIC graphics programs. They'll run with the enhanced graphics.

Greater programming convenience

For greater convenience in programming, several new commands have been added to the new releases of TEK SPS BASIC. For example, there is now a HASH command which assists recorded I/O file access. Also, an LST command produces program listings with indented FOR/NEXT loops and clearer separation of multiple statement lines. And terminal control characters can now be used to suppress or resume output to a terminal.

Those are just a few examples of the additions for your programming convenience. Many other commands and drivers have also been extended with options not included in previous release of the software.

7612D commands added

Two commands have been added to support signal acquisition with the new 7612D Programmable Digitizer. One command is for signal averaging, and the other is for fast logging of 7612D data to peripheral storage. With these two new commands, it is possible to handle as many as one hundred 256-point waveforms a second from a 7612D Programmable Digitizer installed in a WP3201 system.

More waveform storage

The extended memory version of TEK SPS BASIC software (V02XM-02) is designed to handle a higher volume of waveform data than the previous version. Intended for use with a Digital Equipment Corporation PDP-11 minicomputer with KT11D Memory Management hardware, this extended memory version of TEK SPS BASIC adds 96 kilowords of memory for storage of floating-point and integer arrays. That means you now can have a total of 124 kilowords of user-available memory—the standard 28 K for software and program storage and 96 K for waveform arrays. For very much processing of large arrays, such as can come from a 7612D Programmable Digitizer, this additional memory is a necessity.

And it's all compatible

Perhaps the best news is that both of the new releases of TEK SPS BASIC are designed to run programs written on the previous release. But then you'll probably still want to do some modification of older programs to take advantage of the new features in TEK SPS BASIC V02-02 and TEK SPS BASIC V02XM-02.

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