A new breed of digitizing oscilloscopes quickens automated testing by exploiting the innate ability of human beings to recognize patterns generated by waveform enveloping.

Human pattern recognition speeds automated testing

Production test engineers often assume that to increase efficiency they must remove the human element from the test environment. The truth is, people are sometimes the best solution. Man and machine can actually complement each other, with the computer controlling the instruments and making decisions and the operator not only serving as the computer's hands but also offering exceptional pattern recognition talents.

New pieces of IEEE-488-compatible equipment, like the 7D20 programmable digitizer, can raise the efficiency of a production test system. They help by increasing the synergy between man and machine and by simplifying the translation of measurements into a form that can be understood by a computer. Automated testing is complicated by a number of factors, including the computer's execution time, the accuracy and completeness of a measurement, the data acquisition time, and the data retrieval speed. Overshadowing all these complications is the enormous amount of time it takes to translate measurements into computer-usable algorithms and then debug them.

INSTRUMENTS SPECIAL

For example, relying on computer recognition techniques for certain measurements could become a monumental task. Suppose that a test procedure calls for adjusting, say, the step response of a servo amplifier to achieve a rise time of between 40 and 125 μs, a maximum overshoot equal to 25%, an amplitude between 17 and 19 V, and a 5% settling time in less than 250 μs. Assuming that the rise time affects all of the other parameters, how can the testing and adjustments to the specified limits be automated?

One approach is to have an operator adjust the rise time while the computer continuously analyzes the changing waveform until everything is within the specifications. The operator must go slowly so that once the computer is satisfied, it can tell him to stop. Unfortunately, no sophisticated programs optimized for speed can prevent the operator from "tweaking" a bit too much; therefore the computer's judgment frequently differs from the reading the operator finally sees when instructed to stop.

A simpler solution does exist, however, in the innate recognition skills of human beings. People can identify extremely complex patterns virtually instantaneously when compared with today's computer techniques. Because a digitizing oscilloscope has the potential to display multiple waveforms, it can present stored patterns, or "templates," that define upper and lower tolerance limits, thereby replacing the familiar Mylar CRT overlays and grease-pencil marks with digitally stored waveforms. In the case of the servo amplifier, a procedural message and a limit pattern—both displayed on the digital scope's CRT—visually guide the operator toward the proper adjustments to the step response (Fig. 1).

The computer first sets the digitizer's controls, ensuring that the signal can be adjusted to fit the limit pattern. The operator quickly makes the required adjustment and indicates completion by pushing a button at the probe's tip. The computer then responds, extracts the current waveform, and

Clark Foley, Product Line Manager
Tektronix Inc.
P.O. Box 500, Beaverton, Ore. 97077

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verifies that it is within the limits. If the signal fails, the computer forces the operator to repeat the procedure. If it passes, the operator is notified and a new procedure begins. With this approach, the computer is not tied up constantly, the operator participates, and communication between the two is synchronized—in many cases a far more efficient technique.

Generating patterns for visual comparisons leads to many possibilities. Relatively simple patterns, such as two horizontal lines, can describe a dc level or the limits for aberrations or noise. There is seldom any difficulty in creating patterns like that. However, a pattern that accurately describes rise time, amplitude, percentage of overshoot, and settling time—as with the servo amplifier—is highly complex. Furthermore, though the pattern can be designed graphically by calculating the slopes and inflection points, the procedure might take too much time. Besides, the upper and lower limits of the graphic representation may differ from the actual test signal and may only confuse someone who is faced with three waveforms at the same time. Some contrast or visually distinctive method is needed.

Waveform enveloping

The 7D20 offers an attractive alternative. Rather than computing or building waveshape patterns, it permits storage of actual waveshapes.

The test programmer simply takes an actual test signal and adjusts it within its defined upper and lower limits. The waveform enveloping function then records the maximum and minimum excursions, and a pattern is generated from those values within seconds. The enveloping feature displays the upper and lower values alternately as a single waveform. A vector generator then paints in the region between these limits. The vectors simply connect actual displayed dots to simulate a continuous trace. The resulting envelope is a vivid and unmistakable test pattern that cannot be confused with the input test signal.

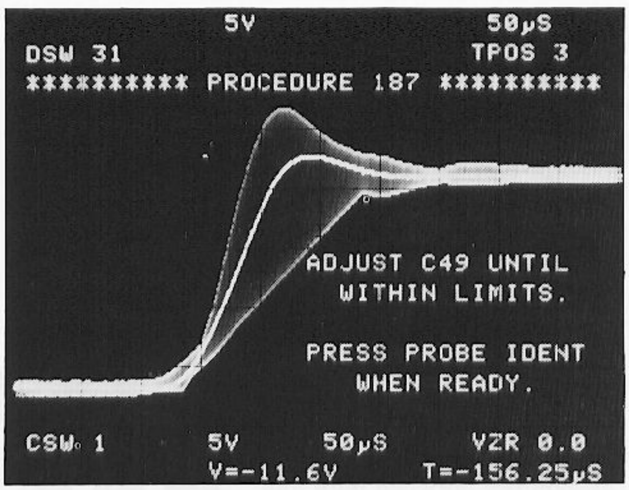
With that enveloping feature in mind, consider the process of calibrating electronic equipment. Dc levels are usually set before moving on to the more dynamic signal characteristics. Obviously a digital multimeter can be used, but if an operator is making the adjustment, an LED readout may not be the easiest method.

The 7D20's display features allow the operator to receive instructions while observing the result of the adjustment. Instead of looking for numbers in a readout and instructions from another display or a written procedure, the operator concentrates on a single display for everything (Fig. 2). The pattern also delimits the allowed range for the adjustment; a DMM readout cannot do that.

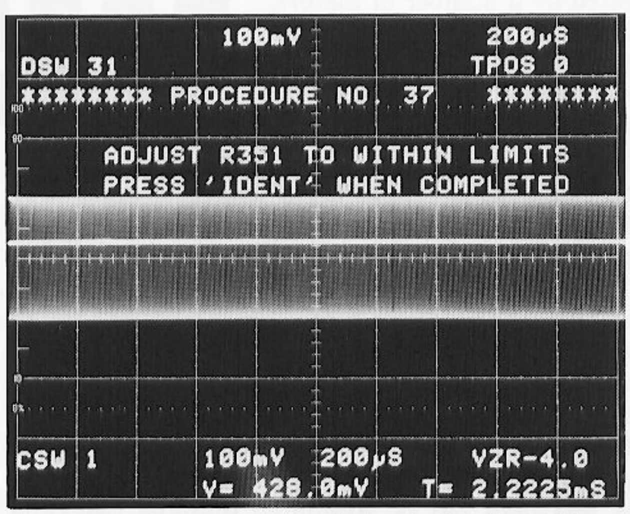
Although the horizontal band display significantly improves human interaction, it is extremely limited, especially in the face of a minor complication, such as when two dc calibration levels must be adjusted. Because adjusting one setting influences the other, the two adjustments cannot be performed independently.

Making interdependent adjustments

Conceivably, two horizontal bands can be used to make that adjustment. To that end, the 7D20 can display two input patterns that are overlaid on two



1. The 7D20 programmable digitizer, which plugs into most 7000 series mainframes, displays a limit pattern, operator instructions, and an active digitized trace on the oscilloscope's screen. After fitting the trace within the limit, the operator pushes the probe's IDENT button, advancing the computer to the next step.

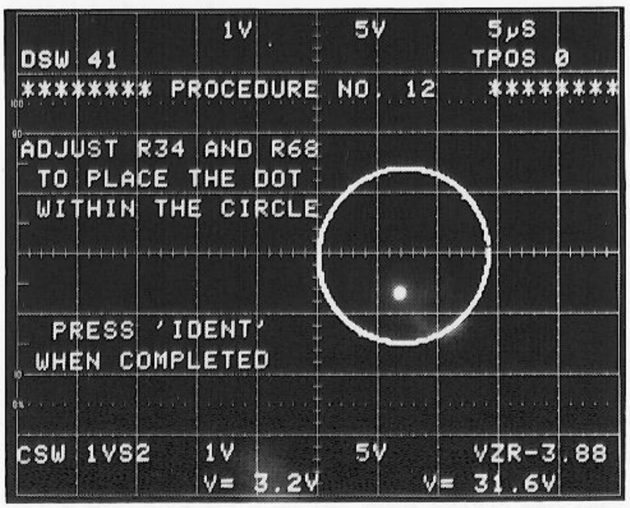


2. Thanks to its waveform enveloping funtion, the 7D20 generates a simple limit pattern along with instructions for setting a dc level in a calibration procedure. The readout at the bottom—V = 428.0 mV—indicates the dc value.

stored envelope patterns, but the displayed information might be extremely difficult to decipher. Furthermore, the pattern is overly complex and becomes a good source for error. Fortunately, that is not the only pattern that can be used. A little extra thought leads to the pattern shown in Fig. 3. Here the circle serves as the target, and the dot's position is driven horizontally by one input and vertically by the other input. Thus a complex problem is reduced to a simple game, with the operator making both calibration adjustments until the dot falls within the circle.

That adjustment poses an overwhelming programming task if left to normal measurement techniques. Here, however, the operator's dexterity and pattern recognition skills reduce the computer's analysis tasks merely to awaiting the operator's signal (via a button at the probe tip), retrieving the vertical and horizontal coordinates of the dot and verifying that they are within limits. Those coordinates are the values of the 7D20's cursor position.

In Fig. 3, only one cursor is used. It reads the voltage values of a waveform with respect to ground (0 V) and the time values with respect to the waveform's trigger point. However, the dot in the pattern is produced by an X-Y display. Channel 1's



3. The calibration of two interdependent dc levels, usually a difficult task, is reduced to a simple visual pattern. The bottom readout shows the dc value of channels 1 and 2 for the X-Y display. The circle is a manufactured Y vs X pattern of two sine waves 90° out of phase.

voltage drives the spot vertically and channel 2's voltage drives it horizontally. When using an X-Y display in that manner, the cursor's readout is essentially the Cartesian coordinates of the dot's position and the origin is the zero voltage values for each input channel. Therefore the computer has to retrieve only the cursor's coordinate values and not an entire waveform to get the values, making an already simple procedure even more efficient.

Parameter subsets simplify testing

Similarly, complex waveshapes need not be analyzed exhaustively if that is not desired. While computer analysis techniques are capable of fully characterizing waveforms, usually subsets of parameters are tested in order to gain analysis speed. The system designer faced with developing these tests from scratch might be interested in still another approach.

As mentioned before, patterns simplify the work done by the computer and the programmer. Using accurate patterns effectively reduces the waveform parameter testing to a simple comparison of data arrays. A single pattern test using some sort of DO LOOP with a "greater than" or "less than" conditional test can determine simply if the waveform is good or bad rather than quantify its entire characteristics. That saves an enormous amount of time in the development and execution of a program. In fact, one pattern test can be used to report passed or failed conditions for a pulse's rise time, fall time, overshoot percentage, settling time, width and for its maximum, base-line, and plateau amplitudes (Fig. 4). Again, the 7D20's waveform enveloping function furnishes the means to generate that complex pattern easily.

Understandable commands

Now the pattern is sent to the computer, where it resides until recalled on the production floor. It is also necessary to record all of the instrument settings and the necessary prompting messages. When any of that information is desired, the test programmer queries the 7D20 and it responds. For example, if the programmer wants to extract a waveform, he issues the query WAVFRM? and the computer responds with all of the scale factors, offsets, memory locations, and data values. If the interest revolves around the front-panel settings, the programmer simply enters SET? and the present setup is returned to the computer. Once recorded, that setup message can be sent back to the 7D20 without any need to duplicate the settings.

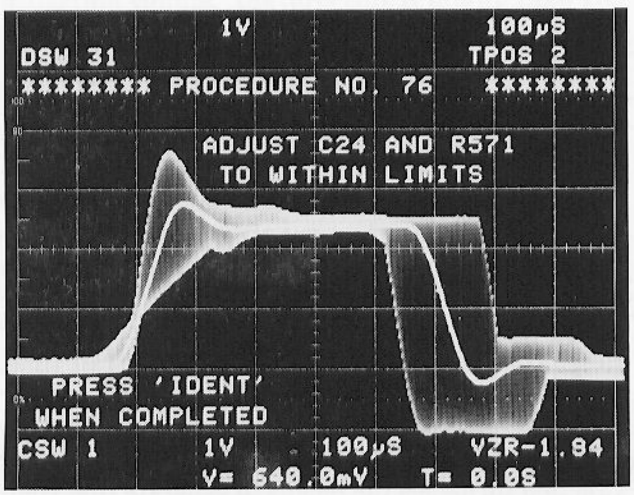
But what about commands that are composed on the computer? In that case, the 7D20 communicates in an English-like command structure. To prevent unnecessary confusion, most of these commands appear on the front panel. Any oscilloscope user should be able to interpret the command

CH1 VOLTS:5.0,COUPLING:DC,POSITION:1.68

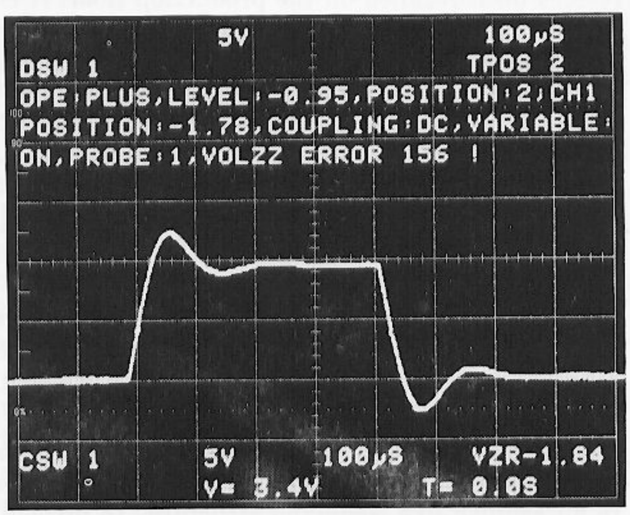
As for interrogating the instrument to determine its present settings, the procedure is simple. To obtain channel 1's settings, the inquiry is CH1?. The response is

CH1 VOLTS:5.0,COUPLING:DC,POSITION:1.68,
VARIABLE:OFF,PROBE:10

Not only does the digitizer thus speak for itself, it also communicates with the user in English. One advantage to that is self-documentation of the control programs. That is, someone reading such a statement in a program listing should have no doubt about what the original programmer was up to. Any combination—ranging from a single setting (e.g., CH1 POSITION) to the entire instrument setup—can be queried.



4. A single pattern can characterize such complex waveform parameters as rise time, fall time, settling time, overshoot, and various amplitudes. A simple comparison of upper and lower limits substitutes for analytical techniques in pass/fail procedures.



5. The 7D20's debugging feature monitors all information sent over the IEEE-488 interface. Error number 156, displayed above, means the symbol VOLZZ is invalid.

The English-like structure, although easy to read, is lengthy and could consume too much time during system operation. An alternative is provided through shorthand or abbreviated messages, which can be called up by the interface command LONGFORM OFF. When that command is selected, a minimum number of characters—each representing unique mnemonics—is sent, reducing the message lengths by approximately one-fourth. A shortform message can be sent to the 7D20 at any time, independent of the LONGFORM OFF command.

Debugging the test program

But what happens when it is time to play everything back? If the program does not work as designed, an arduous debugging task might result. One major problem in debugging an instrument system involves monitoring what is being received by the instrument. Finding out what information was sent to an instrument is easy, but determining how it was interpreted is not.

Typically an instrument responds to a "misinterpreted" signal with some nebulous warning or error message. If an error or warning is indicated by the 7D20, the operator can inquire about the event responsible by using EVENT?. The response is a unique code detailing the cause, and more than 100 different error conditions can be reported, including those originating in programming or front-panel settings.

Though the evidence required to diagnose bugs can thus be obtained through the computer terminal, it still may not be possible to decide exactly which command produced the error.

By considering the human factor, a unique command—DEBUG—was developed for the 7D20 that has proved most valuable for program development. When activated, it displays every character sent to the 7D20 right on the instrument's CRT. If an error has occurred, an error message is inserted immediately following the error. The display pauses, allowing time to spot the mistake, and then continues executing and monitoring the commands (Fig. 5). Now the operator knows exactly what was received and what caused the error—there's no more hunting for bugs in the dark. □