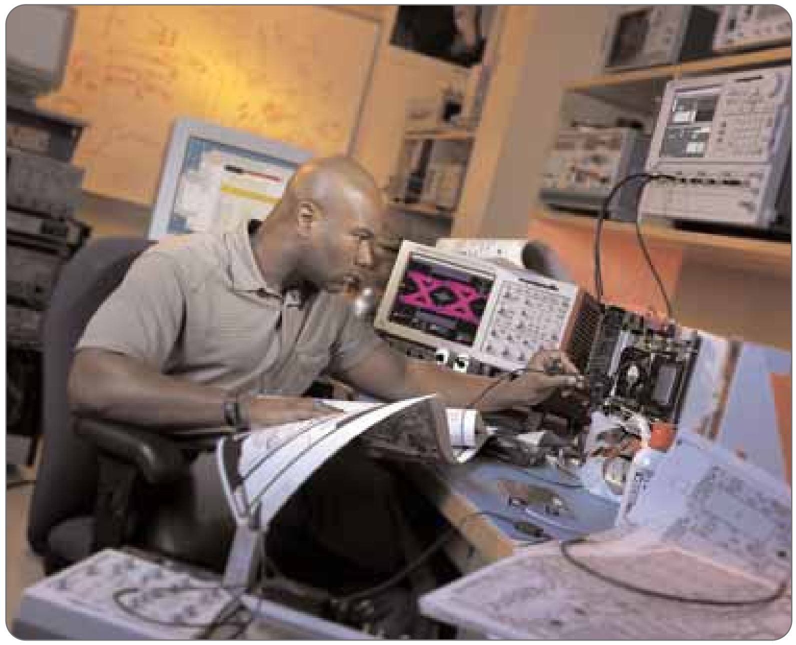
DPOs Deliver More Signal Information for Faster Design and Troubleshooting Answers



▶ **Powered by DPX™ acquisition technology, the latest DPOs allow designers to capture, view and measure dynamic signal information much more quickly and easily than other oscilloscopes, to propel a serial bus design ahead to meet a tight schedule, or to solve erratic troubleshooting problems quickly.**

Introduction

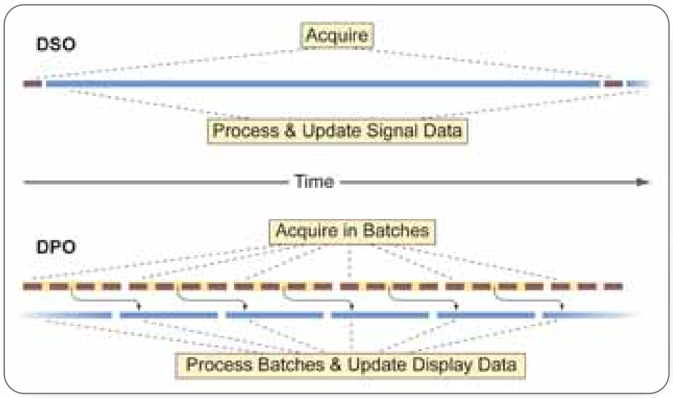
Since its arrival, the digital phosphor oscilloscope (DPO) has changed the way engineers capture, view, and measure dynamic signal information. The latest DPOs such as the TDS7000B, TDS5000B, DPO7000, and DPO70000 general purpose oscilloscope models as well as the DSA70000 Digital Serial Analyzer Models offer all the traditional benefits of a digital storage oscilloscope (DSO), from waveform data storage to powerful triggering. But these DPOs have a crucial advantage not found in any DSO, namely, an extremely large waveform capture rate. Orders of magnitude faster than conventional DSOs, this capture rate allows the oscilloscope to accumulate detailed information about the signal very rapidly. As a result, the DPO offers unsurpassed measurement and analysis throughput and, at the same time, gathers useful frequency-of-occurrence information.

In this application note we will discuss the architecture and operation of the DPO, then present some application examples that clearly demonstrate the benefits of DPO acquisition.

A Different Approach to Acquisition

The DPO's waveform capture rate sets it apart from other acquisition architectures (conventional DSOs and sampling oscilloscopes). Many oscilloscopes in Tektronix' offerings are DPOs whose performance is powered by integrated DPX™ technology, a unique parallel-processing architecture that dramatically reduces the oscilloscope's acquire/process/update cycle. DPX is the enabling technology that delivers more than 25 times what a traditional DSO offers in terms of waveforms per second (wfms/s). It is a parallel processing architecture that manages display and acquisition systems separately and creates waveform images as fast as the signal can be triggered.

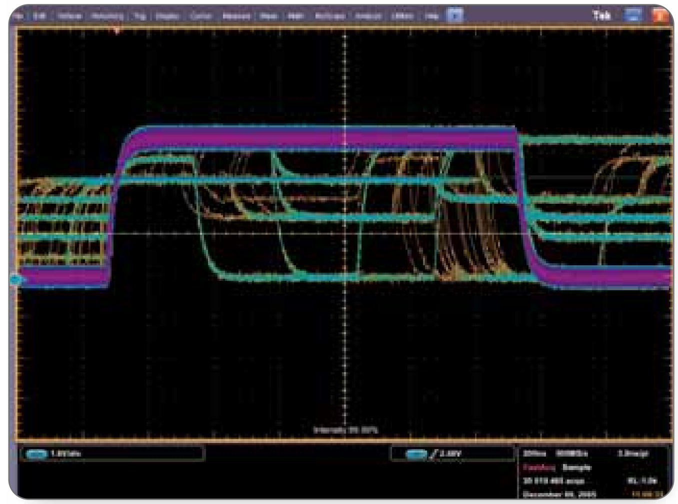
Tektronix
Enabling Innovation



▶ ***Figure 1.*** *With its parallel-processing architecture, the DPO carries out many acquisitions in the time it takes a DSO to complete a single acquisition/processing cycle.*

Why is the waveform capture rate so important? The answer is simple: the DPO "discovers" more because it "looks" more. The exceptional capture rate of a DPO means that infrequent events are far more likely to be acquired. And its intensity-graded color display makes it easy to distinguish even a one-time event amid thousands of cycles of the waveform. DPO speeds troubleshooting and analysis wherever it is used. Compare a DPO to a DSO, which acquires signals only a small fraction of the time—often less than 1 percent. The highest DSO capture rates are in the range of about 7800 waveforms per second. Most of the DSO's time is spent processing the acquired waveform data and creating the display. Signal activity occurring during that interval cannot be observed.

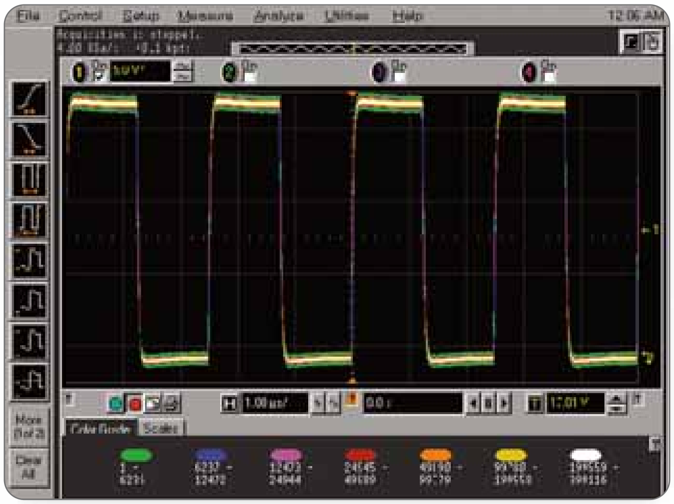
The DPO uses parallel architecture to shrink this processing time dramatically, and proportionally increase the time spent observing the signal. Its extremely large waveform capture rate is more than 25 times that of the fastest DSO. Common sense tells us that the DPO, because it is "awake" so much more of the time, will tend to capture more information about passing events. That means greater insight into critical signal behavior and more data for in-depth analysis.



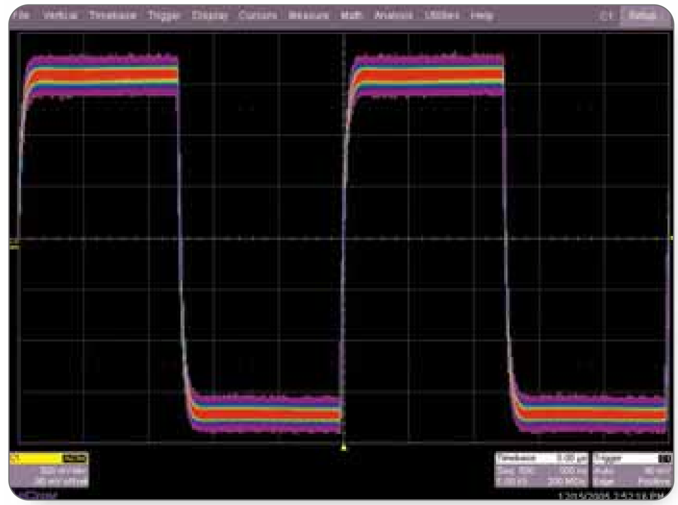
▶ ***Figure 2a.*** *DPO acquisition.*

Figure 1 illustrates the concept. During the same long timespan the DSO uses to compile just one image, the DPO continues to capture and accumulate many batches of waveform images. For the sake of legibility, Figure 1 is not drawn to scale; in actual operation there are many more DPO acquisitions than can be shown here. Again, more acquisitions mean more opportunities to catch momentary changes in the waveform.

The capture of more information is not just an abstraction; it is a concrete benefit that speeds troubleshooting, among other tasks, and enhances the analysis of complex signals. Figure 2a, 2b, and 2c use a square pulse signal waveform to prove the point. In Figure 2a, the lighter trace areas indicate a lower frequency of occurrence — areas that the waveform has touched less frequently. Aberrations are clearly revealed – in this case, a secondary waveform exhibiting phase shift and occasional truncated pulse amplitudes. In a DSO acquisition (Figure 2b or 2c), the instrument has spent its time compiling the display rather than acquiring a fast succession of waveforms.



▶ ***Figure 2b.*** *DSO acquisition.*



▶ ***Figure 2c.*** *DSO acquisition.*

As a result, after one minute of acquisition, it has completely missed anomalies that could cause serious problems downstream in the circuit. The signal appears normal, a false conclusion that could mislead subsequent troubleshooting steps.

In this example, the DPO has revealed the true nature of the signal activity. It has captured much more signal data, and it has done its job quickly. This voluminous information can help answer common troubleshooting questions:

- Are transient events corrupting my signals?
- Does my signal have jitter or other timing aberrations?
- What are the measured parameters such as peak, mean, average, and more?

Getting Speedy Results

Because a DPO gathers more waveforms in less time, it has another implication for the oscilloscope user: detail-rich displays and deep analytical databases accumulate in seconds rather than minutes. A powerful acquisition mode known as FastAcq, powered by DPX™ acquisition technology, provides the shortest, fastest processing path to bring waveforms to the display screen. Aside from its ability to reveal transient information, the DPO can build eye diagrams, polar charts, constellation diagrams and associated databases almost instantly. Recognizing the value of the DPO's exceptional throughput, the market responded by adopting Tektronix DPOs for many measurement applications. Industry committees such as the Digital Display Working Group (which is responsible for guiding the Digital Video Interface, DVI, standard) have standardized on the DPO and the FastAcq mode, for compliance testing. The FastAcq mode builds an image database of frequency-of-occurrence data, although this database is not as comprehensive as that of the WfmDB mode explained below. The FastAcq mode is a powerful tool for the engineer who needs to capture a complex signal, or even an eye pattern in all its detail, including aberrations.

A second acquisition mode, known as WfmDB, accrues a continuous database about the waveform parameters. Designed to maximize measurement and analysis throughput, the WfmDB mode minimizes the processing time between acquisitions by quickly accumulating a "batch" of acquisitions, then processing them. It can be configured to acquire a preset number of samples, which are collected over many acquisitions. When this mode is selected, a "Samples" menu choice appears, allowing the user to set the proportion of information that is saved in the database versus the number of acquisitions displayed. As a rule of thumb, the WfmDB mode is best used for analysis, while the FastAcq mode supports troubleshooting and measurements.

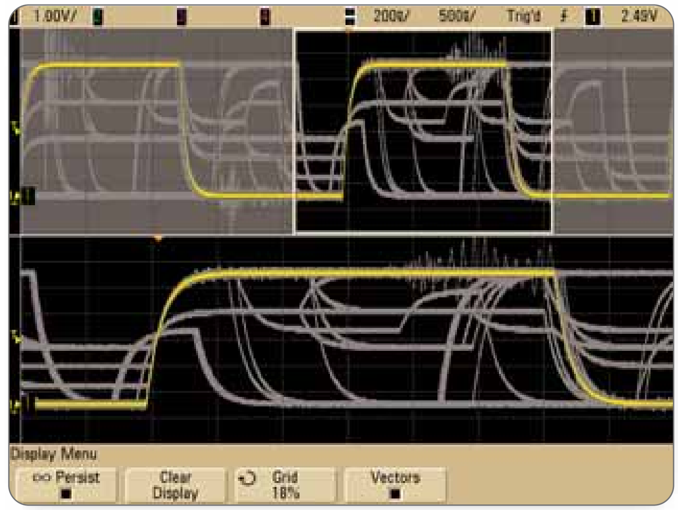
DPO Takes Persistence Mode a Step Further

Oscilloscopes have for years included a display feature known as the persistence mode. The mode originated with analog oscilloscopes. The display's phosphor retained the image of the waveform trace for a few moments after the trace had passed, allowing closer scrutiny of signal details.

DSOs emulate persistence by post-processing captured waveforms and emulate an intensity-graded display. But DSO persistence is limited to displaying information captured at the infrequent rates discussed earlier. It cannot benefit of the higher rates used in a DPO particularly for detecting irregular events. The display does not reveal real-time details. Intermittent events that occur during the processing and display formatting cycles may be missed.

Another display solution is intensity modulation which brightens the trace to make the details of long waveform records more visible. Though useful for enhancing coarse details, this feature does not address the issue of waveform capture rate, nor does it grade the intensity of individual signal elements. The infrequent components brighten up along with the main trace rather than becoming more distinct.

Recently, some alternative platforms have come to market claiming true intensity-graded displays as well as high capture rate (Figure 3a). However the waveform trace itself is monochrome - there is no color dimension to highlight the differences in frequency of occurrence. Without that attribute, transient events can become almost invisibly faint on-screen. In the DPOs, a frequent event is bright and orange, for example, while a less frequent event is blue - but still bright and readable. This characteristic is especially valuable when reading eye diagrams and also helps to spot easily glitches, truncated pulses or other aberrations.



▶ ***Figure 3a.*** *Competitive alternative approach to DPO, however the trace is monochrome and has no frequency dimension.*

DPX™ acquisition technology is not the same thing as persistence mode, although the basic DPO display mode provides many persistence-like benefits in real time. Intensity grading (sometimes described as greyscaling) is achieved by overlaying thousands of acquisitions into every screen update, and does not require a time-consuming accumulation of waveform images. Even so, DPOs also include a persistence mode. The DPO's high waveform capture rate maximizes the likelihood of detecting transitory signal details, while persistence can be used to sustain these details on-screen for evaluation.

Applications Demand a Strong Measurement Platform and Detailed Signal Information

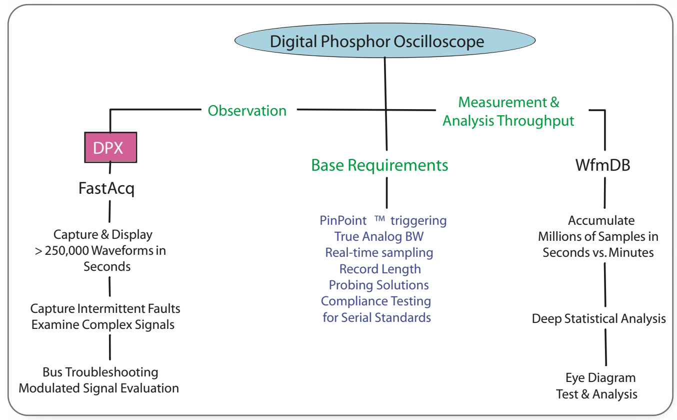
To the designer working with high-speed signals, the latest measurement challenges continue a familiar trend: faster data and edge rates, and narrower timing tolerances. DPX technology enables designers to meet these challenges by providing more signal visibility and more waveform detail than other acquisition tools.

Any discussion about DPO applications assumes that the instrument's base platform is sufficient to meet the fundamental measurement requirements:

- Sufficient analog bandwidth, and a sample rate that meets or exceeds Nyquist Theorem requirements at the signal's frequency
- Differential probing solutions that make the oscilloscope's full specified bandwidth available at the probe tip
- Comprehensive triggering with ultra-low jitter, conditional modes, and flexible clock recovery
- Compliance test or automated measurement software as applicable

Given a DPO with these features, the next step is to choose the acquisition mode – FastAcq or WfmDB – that best suits the application. Figure 3b contrasts the strengths of these two modes.

The balance of this application note will be devoted to a discussion of these modes and how they are used to accomplish real-world jobs: digital troubleshooting, mask testing, and IQ signal measurements. The application scenarios that follow are not meant to define comprehensive procedures for their respective measurements. Rather, they summarize the basic steps to acquire a waveform and analyze it either visually or with the DPO's built-in measurement tools.



▶ ***Figure 3b.*** *The DPO's FastAcq and WfmDB modes provide optimized tools for a wide range of applications.*

DPO7000, DPO70000 and DSA70000 Series take DPOs to the Next Level

The DPO7000 Series and the DPO70000 Series oscilloscopes as well as the DSA70000 Digital Serial Analyzers set the pace for bandwidth, sample rate, memory depth and triggering and related performance attributes in their relative performance category of their class. Equally important, they raise DPO performance to the next level:

- They offer up to more than 250,000 waveforms per second sustained on four channels simultaneously. This is unsurpassed by any other solution in their class. This level of capture rate will speed troubleshooting work for designers by making it easier to acquire erratic or momentary events on all 4 channels simultaneously.
- DPO acquisition occurs at all sample rates and up to the instrument's maximum real time sample rate. This is an increase over previous generation whose real time sample rate was limited to 1.25 GS/s in DPO acquisition.
- The horizontal resolution has been improved to take full advantage of the industry's largest 12.1 inch XGA display. The horizontal resolution has been doubled from 500 columns to 1000 columns.
- The vertical display has increased from 8 divisions to 10. These enhancements will make it easier to accurately interpret both the amplitude and the timing characteristics of the waveform by displaying the full range of the A/D converter over the 10 divisions.
- The depth of the data within the statistical database has increased from 4 bits to 26, dramatically extending the waveform history and increasing the measurement accuracy in DPO acquisition.
- There are now 32 levels of intensity grading versus 16 in previous DPOs and competing designs to distinguish the signal's frequency of occurrence.
- This new generation of DPOs brings major enhancements to the proven and successful major enhancements to the proven and successful Digital Phosphor Oscilloscope architecture and solidifies the strengths of the DPO platform as a powerful, productive design and troubleshooting tool.

Application #1: Troubleshooting Digital Timing Violations and Bus Conflicts

Race conditions, setup/hold violations and bus conflicts can all wreak havoc in a digital system. If there are race conditions or setup/hold timing violations, brief glitches and other aberrations can result. In a bus conflict, glitches are also common, as well as the truncated “runt” pulses caused by two drivers simultaneously trying to force opposing logic levels on the same wire. A DPO innately detects and displays the effect of these types of errors. The procedure is simple and fast:

1. Press Default Setup on the front panel, connect the probe to the signal of interest, and press Autoset. The signal will appear on the display, scaled and centered.
2. Push the Edge trigger button on the front panel, or push the Advanced trigger button and select an appropriate trigger from the Trigger Menu. In many cases, Edge triggering will suffice for the first look at a signal. More advanced triggering, such as a state trigger, can be employed to qualify the data you want to observe.
3. Choose the trigger type and state, and specify the logic levels and pattern type if appropriate. In this example, basic Edge triggering will provide a stable waveform since the signal is a simple pulse train.
4. First, note the look of the waveform. Now, press the purple FastAcq button on the front panel (Figure 4). Observe how much more information is presented with the simple push of a button.
5. On the Display Setup window, Appearance tab, set Persistence to Infinite. This allows aberrations to stand out prominently, even if they are very infrequent. On the Colors tab, set the color-grading scheme to Spectral. This will effectively highlight infrequent events in red.

The resulting display is shown in Figure 5. The FastAcq mode builds the display in just a few seconds. In Figure 5, the least frequent events are depicted in red. Each red pixel defines a point the waveform has crossed sometime during an acquisition cycle. Because the Persistence is set to Infinite, the occasional flawed pulse shows up very clearly. In the pulse at the center of the screen, we see both a glitch and a truncated pulse aberration. The glitch might imply a setup/hold violation, race condition or metastability problem. The runt pulse implies a bus conflict. Further investigate these faults by setting up an advanced trigger to isolate and capture additional occurrences of a particular anomaly. Probe other signals that may lead to the problem’s cause, such as buffer enables and data direction select lines. In addition, the oscilloscope can be linked to a Tektronix TLA Series logic analyzer via the iView™ Tool Set, to see both the TLA’s digital timing traces and the oscilloscope’s analog trace in perfect time-alignment.

▶ ***Figure 4.*** *Simply press the FastAcq button on the front panel to unleash the power of this acquisition mode.*

▶ ***Figure 5.*** *The DPO highlights the aberrant traces in red. Because Persistence is set to infinite, the display maintains the trace for easy viewing and assessment.*

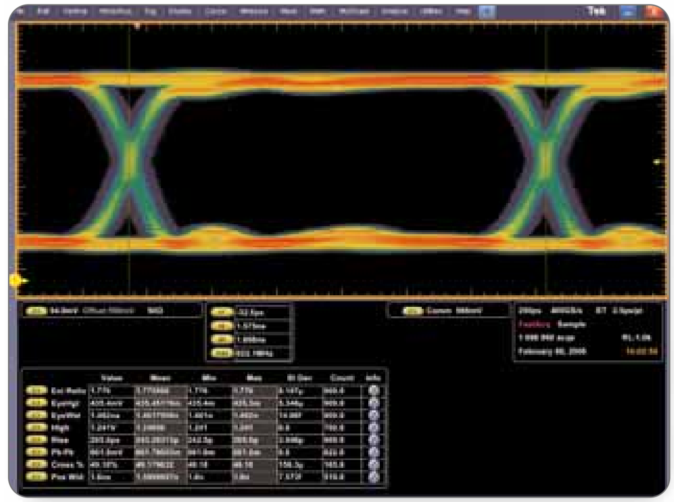
Application #2: Eye Pattern Measurements and Mask Testing

Basic Eye Pattern Measurements Using FastAcq Acquisition Mode

The FastAcq acquisition mode enhances the rate of signal acquisition and display in order to maximize information about dynamic signal behavior. Unlike a persistence display, FastAcq mode produces a database of values that can be analyzed by many of the automatic measurements; and FastAcq mode can be combined with Persistence modes to present even more information. In this example, we will set up, capture, and measure eye pattern parameters with the basic FastAcq facilities. This is a fast, easy way to assess signal performance with just a few steps. The signal is a 622 Mbs/s pseudo-random signal of the type commonly found in serial communication architectures.

1. Press Default Setup on the front panel, connect the probe to the signal of interest, and press Autoset. The signal will appear on the display, scaled and centered.
2. Press the Advanced trigger button on the front panel to access the Trigger Menu and select Comm triggering. Trigger setup for 622 Mb/s or OC-12 standard and select R Clk (for clock recovery) as the type.
3. Press the purple FastAcq button on the front panel. Notice the immediate increase in acquired and displayed information.
4. On the Display Setup window, Appearance tab, set Persistence to Infinite. This allows aberrations to stand out prominently, even if they are very infrequent.
5. On the Measurements window, choose automatic measurements for Amplitude, Peak-to-Peak Amplitude, and Rise time; and optionally, histogram.

Figure 6 shows the resulting waveform and measurements. Grey-scaling reflects the frequency of occurrence; the darkly-shaded areas denote less-frequent events occurring at the signal transitions. The voltage is slewing rapidly through many sample values and jitter is causing time deviations, creating the wide blue trace. The selected quantitative measurement values appear near the lower right corner of the waveform display.



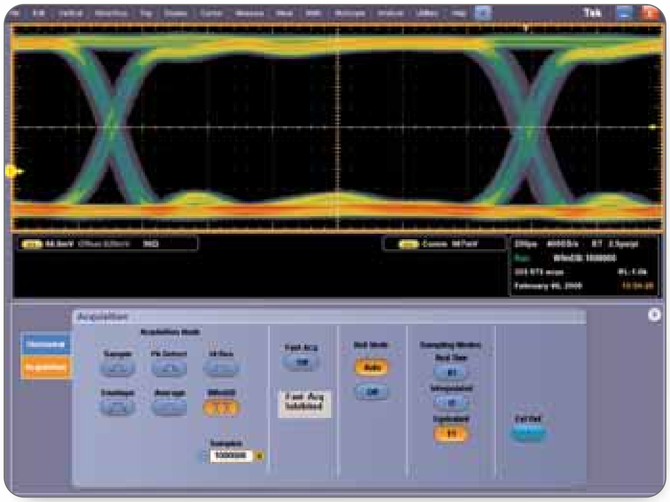
▶ ***Figure 6.*** *Eye pattern and measurements acquired with Fast Acquisition (FastAcq) mode.*

The FastAcq mode is optimum for the observation of signals acquired with high live-time acquisitions. Well suited for fast measurements and speedy signals, data collected using the FastAcq method can be directly analyzed for amplitude characteristics during pre-compliance and troubleshooting.

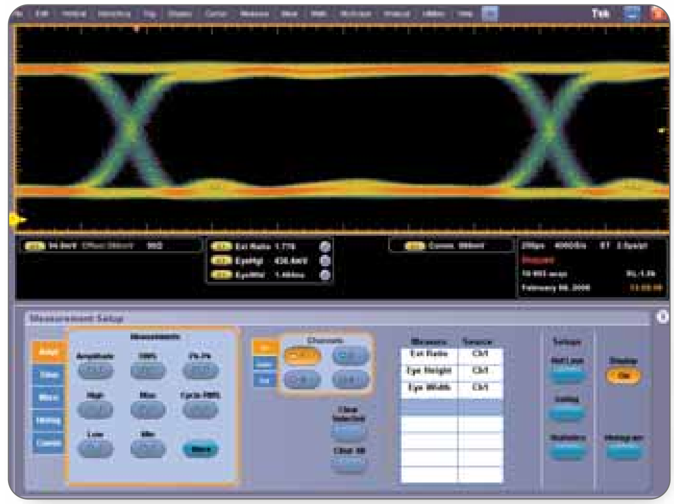
Mask Tests Using the WfmDB Acquisition Mode

The waveform database (WfmDB) acquisition mode provides the tools for analyzing eye patterns as a part of mask and compliance testing. Its storage capacity for critical signal information is much greater than that of the FastAcq mode. The database includes amplitude and timing information about each waveform point, as well as the number of times each specific point has been acquired. WfmDB acquisition mode produces the largest amount of statistically valid information with exceptional speed for investigative analysis, such as eye pattern measurements.

Figure 7 depicts the Horizontal/Acquisition control window, which includes the Waveform Database button and Samples control. This control determines the number of waveform samples that will be stored in the waveform database for analysis. In Figure 7, the Samples control is set to the default value of 1 million samples.



▶ ***Figure 7.*** *The Horizontal/Acquisition control window, showing WfmDB mode selected. Note the "Samples" entry, which allows the number of samples to be specified.*

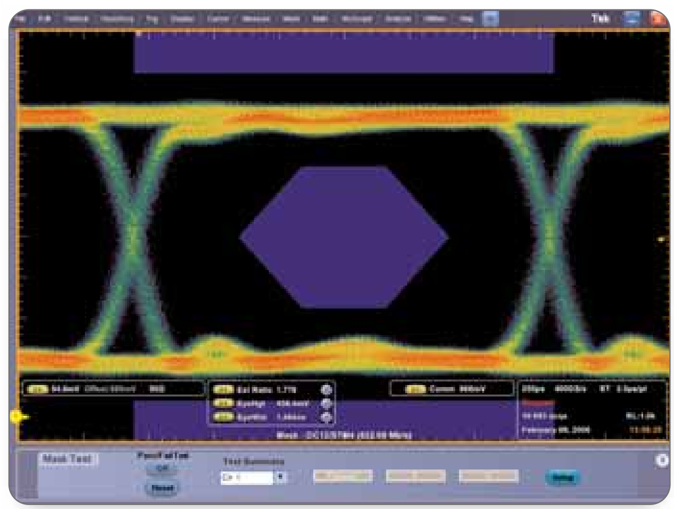


▶ ***Figure 8.*** *The Measurement window, showing measurement selections, sources, and results from the WfmDB acquisition mode.*

To set up a mask test in the WfmDB mode, carry out the following steps:

1. Press Default Setup on the front panel, connect the probe to the signal of interest, and press Autoset. The signal will appear on the display, scaled and centered.
2. Press the Advanced trigger button on the front panel to access the Trigger Menu and select Comm triggering.
3. Select the appropriate mask and reset the oscilloscope using the Mask Autoset function.
4. If any portion of the waveform is off-screen due to overdrive conditions on the input, turn off Persistence if it is on and select a minimal number of samples on the Horizontal/Acquisition control window. This delivers the most responsive display, making it easier to make suitable adjustments in the input signal.
5. On the Measurement window, Comm tab (Figure 8) select the desired measurements: Extinction Ratio, Eye Height and Width, etc. Select the source channel that will provide the signal.

The waveform pane in Figure 8 provides all the requested measurements at a resolution and accuracy consistent with today's rigorous communication bus standards.



▶ ***Figure 9.*** *A pass/fail mask test for an OC-12 signal. The device has passed the test.*

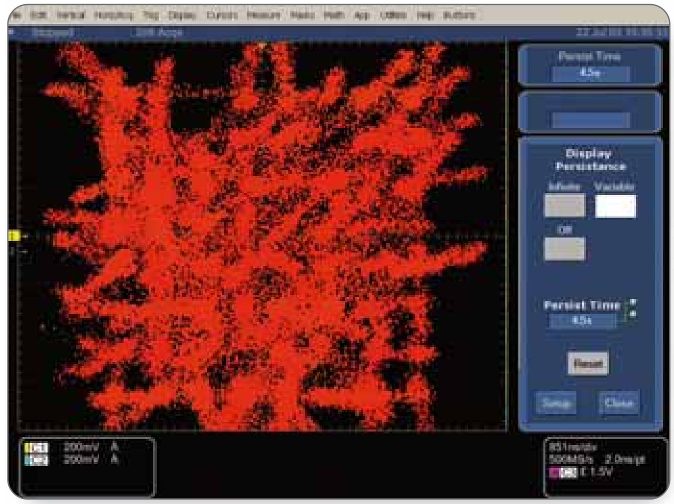
Figure 9 is a mask compliance test on the SONET OC-12 signal obtained by selecting Autoset, and then selecting the mask type – in this case, SONET/SDH and OC-12. This window contains the Pass/Fail Test control, which, when enabled, provides a simplified summary of the test outcome. The mask areas (upon which the signal must not encroach) are shown in blue here. In this window, the quantitative measurements are not the object. Instead, the window tracks whether the blue mask areas have been penetrated by any waveform point. In Figure 9, there are no violations and the test has passed.

Application #3: Evaluating a 64QAM Signal

Interpreting IQ signals is a challenge for DSOs. With their slow waveform capture rate, they must post-process acquisition records before they can display the information. In effect, there is an acquisition, then an interruption to compute and display the trace, then the next acquisition, and so on. The result is an image that simply cannot build up fast enough to make the constellation diagram comprehensible.

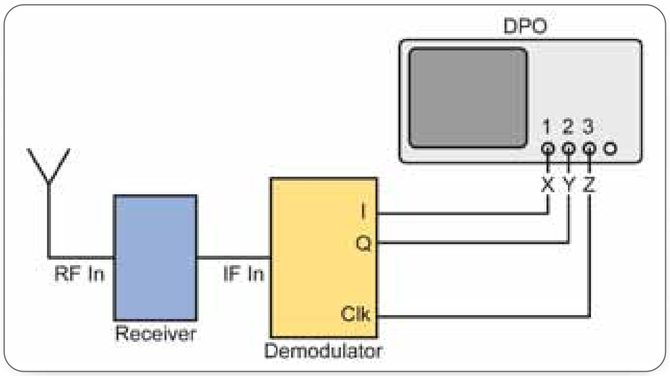
There is also a risk that the record length used for the computations may be too short. Where a waveform that is plotted against a time axis (the normal Y-T display) will make this error visible immediately, the X-Y display produced by post-processing can mask the problem, with misleading results. For example, if only a small fraction of a period of a sine (X channel) and cosine (Y channel) are acquired, it will be immediately obvious in a YT display that a longer record length is needed. In an acquisition based on XY display, however, a straight diagonal line will be drawn rather than the expected oval lissajous figure. The DPX hardware eliminates this problem by drawing a continuous stream of samples rather than discrete acquisitions. Lastly, DSOs lack a true XYZ mode, in which three signal inputs interact to create a time-domain display with an intensity (Z) axis.

Figure 10 simulates the result of an attempt to generate a 64QAM constellation display with a DSO. Only a vague hint of the 64 target locations is visible, and no real data about the frequency with which the targets are hit.



▶ ***Figure 10.*** *This 64QAM constellation display was created by post-processing the acquisition record.*

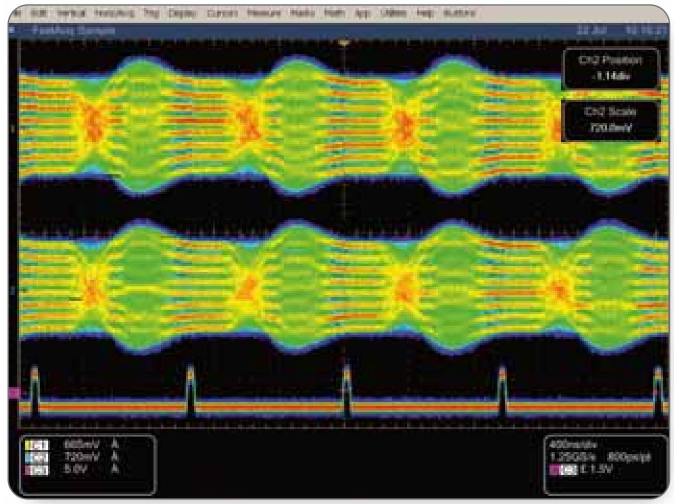
In contrast, DPO acquisition is well-suited for constellation plots of quadrature signals. Thanks to the immediacy of the DPX™ architecture and the FastAcq mode, the DPO continuously acquires samples and sends each X and Y point with an optional associated Z-axis (intensity) value to the screen as soon as it is received. The FastAcq mode builds the display in seconds using the high data throughput of the integrated acquisition and rasterization hardware. Temperature color-grading makes it easy to see how often the modulation points deviate from their ideal "targets."



▶ ***Figure 11.*** *The connections for a 64QAM constellation diagram.*

Figure 11 depicts the connections that will be used to acquire the IQ signals and produce the plot. Three of the DPO's four channels are used; one each for the X, Y, and Z axes.

1. Press Default Setup on the front panel, connect the external demodulator's I output to Channel 1, the Q output to Channel 2, and Clock signal to Channel 3 as shown. Make sure that all three channels are on, and press Autoset.
2. On the front panel, choose Channel 3 (Clock) as the trigger source and push in the Level knob to set the trigger level to 50%.



▶ ***Figure 12.*** *The Y-T display of the 64QAM signal.*

3. Press the purple FastAcq button on the front panel. This produces the Y-T mode display shown in Figure 12. Displaying the clock (bottom trace in Figure 12) is at the user's discretion, since it is not the signal of interest here.
4. On the Display window, choose XYZ mode.
5. Adjust the vertical scale of Channel 1 and 2 and position the resulting display appropriately.

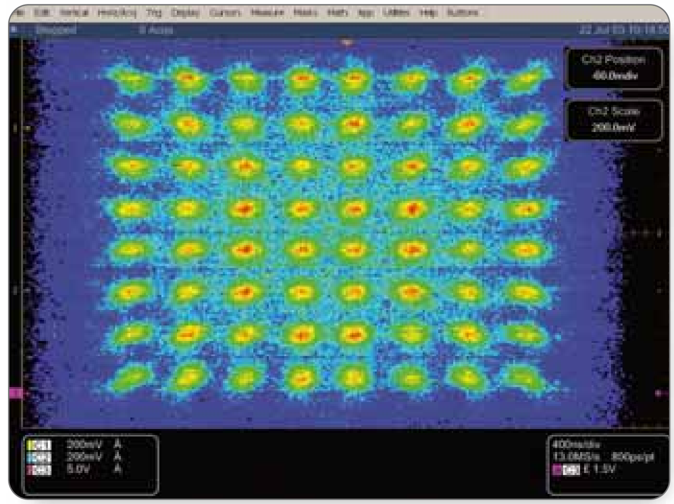
Figure 13 shows the resulting IQ plot as it begins to build, while Figure 14 shows the same plot a few seconds later, with a concentration of points at each 64QAM target.

Conclusion

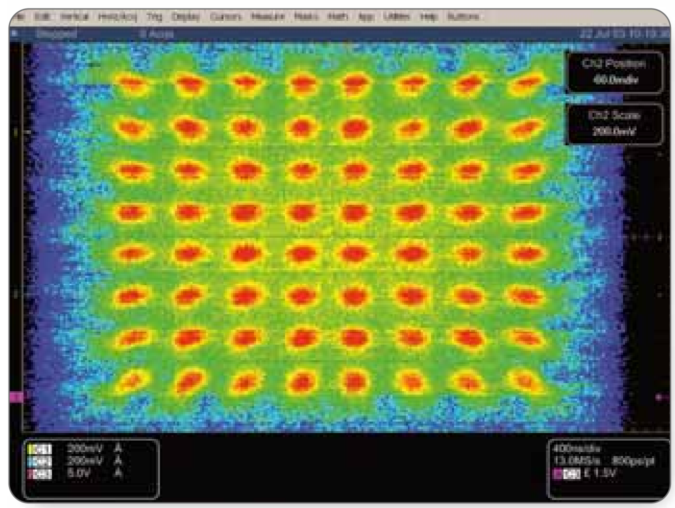
The digital phosphor oscilloscope (DPO) provides new perspectives to designers as they view and measure dynamic signals. Powered by Tektronix' exclusive DPX™ parallel-processing acquisition technology, the DPO waveform capture rate exceeds by at least 25 times traditional DSO waveform capture rate and at the same time enables unsurpassed measurement and analysis throughput.

Using the DPO's Fast Acquisition mode, digital and analog troubleshooting tasks are aided by fast, easily interpreted visual details on the oscilloscope screen. Using the Waveform Database mode, accurate characterization measurements and compliance tests proceed quickly, and eye diagrams are quickly condensed into histograms, quantified parameters, and Pass/Fail results. Both modes are designed to speed the engineer's measurement work. The DPO's efficiency is further enhanced by a simplified control architecture that reduces even complex measurements to a few short steps.

The result of every DPO acquisition is a richly detailed body of information about the signal, far more than just a simple two-dimensional waveform trace. It is information that can propel a serial bus design ahead to meet a tight schedule, or help engineers solve erratic troubleshooting problems quickly.



▶ ***Figure 13.*** *The IQ plot begins to build up.*



▶ ***Figure 14.*** *A "filled-in" constellation plot, using temperature grading to indicate frequency of occurrence of each modulation point. Red indicates the most frequent hits.*

Contact Tektronix:

ASEAN / Australasia (65) 6356 3900
Austria +41 52 675 3777
Balkan, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium 07 81 60166
Brazil & South America 55 (11) 3741-8360
Canada 1 (800) 661-5625
Central East Europe, Ukraine and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France +33 (0) 1 69 86 81 81
Germany +49 (221) 94 77 400
Hong Kong (852) 2585-6688
India (91) 80-22275577
Italy +39 (02) 25086 1
Japan 81 (3) 6714-3010
Luxembourg +44 (0) 1344 392400
Mexico, Central America & Caribbean 52 (55) 5424700
Middle East, Asia and North Africa +41 52 675 3777
The Netherlands 090 02 021797
Norway 800 16098
People's Republic of China 86 (10) 6235 1230
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 82 (2) 528-5299
Russia & CIS +7 (495) 7484900
South Africa +27 11 254 8360
Spain (+34) 901 988 054
Sweden 020 08 80371
Switzerland +41 52 675 3777
Taiwan 886 (2) 2722-9622
United Kingdom & Eire +44 (0) 1344 392400
USA 1 (800) 426-2200
For other areas contact Tektronix, Inc. at: 1 (503) 627-7111
Updated 12 May 2006

Our most up-to-date product information is available at: **www.tektronix.com**

7/06 JS/WWW 55W-16965-2

Tektronix
Enabling Innovation