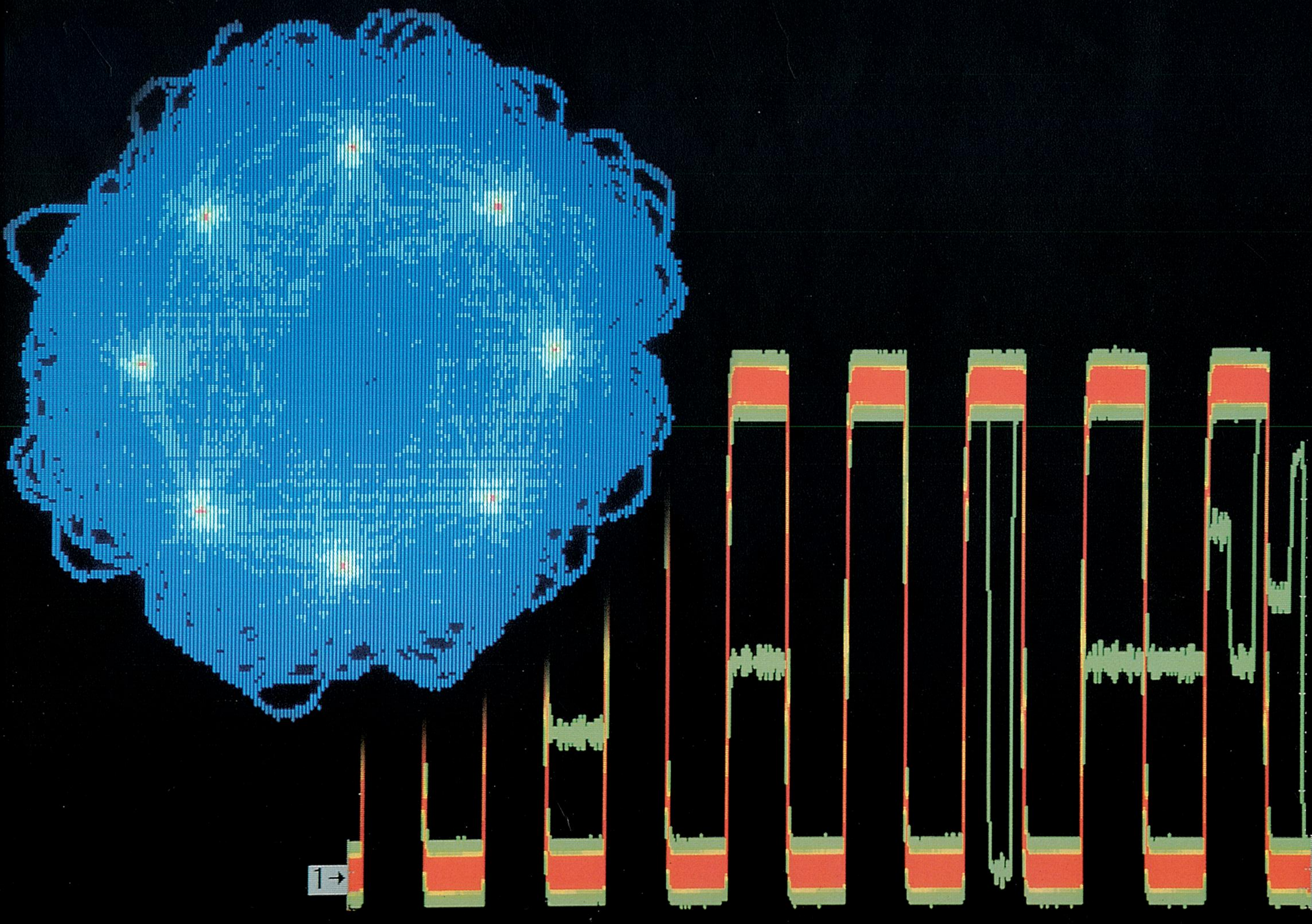
Tektronix

# Oscilloscope Evaluation Guide



## Can your oscilloscope pass the debug challenge?

Your oscilloscope may be the most important single debug tool you own, especially for today's complex designs and communications applications. Faster speeds, growing complexity, more stringent design margins and shorter time-to-market requirements are making many of yesterday's scopes obsolete.

## Tektronix Scope Evaluation Kit.

This Evaluation Kit can help you make sure you have the right scope for your needs. And, we believe it will also help you discover new ways to quickly debug some of today's most challenging – and most common – design problems.

What's in this kit?

1. A small yet highly sophisticated **Waveform Generator Board** produces a wide variety of "real-world" signals, complete with the kinds of anomalies that challenge today's designers.
2. **Oscilloscope Evaluation Guide** (this section) will take you step by step through several test and debug problems to gauge your scope's abilities.
3. **How a DPO Speeds Debugging** will inform you on Tektronix Digital Phosphor Oscilloscopes (DPOs), and the powerful new debugging capabilities they provide.
4. **DPO Selection Guide** summarizes the features and capabilities of Tektronix' extensive family of DPO oscilloscopes.
5. **Technical Reference** section includes debugging application notes and a detailed discussion of the new technology behind DPO oscilloscopes.

## Our promise.

At Tektronix we are committed to providing you with the most advanced measurement tools and the support to help you create new and better designs, on time and under budget. Please contact your Tektronix representative with any questions concerning this Scope Evaluation Kit or any Tektronix products.
Or visit us at www.tektronix.com/measurement.

## Using the Waveform Generator Board

Despite its small size and apparent simplicity, the Waveform Generator Board is a sophisticated device containing a microcontroller that produces signals simulating many of today's real-world problems. To help you accurately evaluate the debugging capabilities of your oscilloscope, these signals contain the kinds of anomalies that present some of your toughest debug challenges.

The figure shows the waveforms present at each test point.

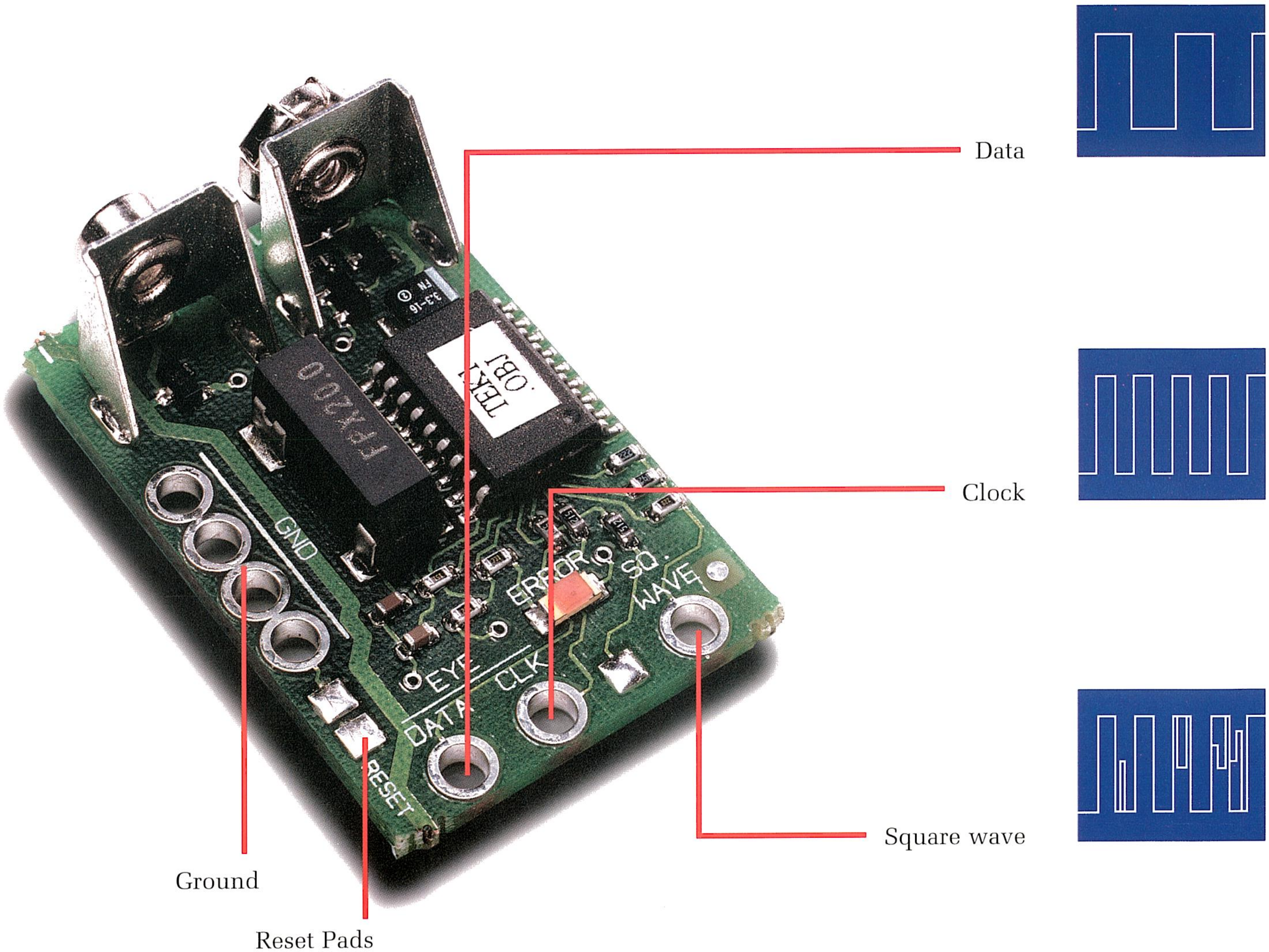
To activate the board, just snap the 9-volt battery in place. The battery will power the board for approximately 8 hours. *(Note: If the LED is not flashing 5 seconds after you connect the battery, disconnect, wait approximately 15 seconds, and reconnect the battery; or you may short, for two seconds, the two square pads next to "Reset" on the board.)*

To conduct the tests in this Evaluation Guide, you will need the following:

1. A Digital Storage Oscilloscope (DSO) or Digital Phosphor Oscilloscope (DPO)
2. Three 10X probes
3. A watch with a second hand

**Notes:**
**On the pages that follow we provide images of what you may see on your DSO. Depending on the type of instrument you are using, your results may vary from these images.**

**If some of the terminology used in the exercises is unfamiliar, please refer to the section "How DPO Speeds Debugging" for clarification.**


Data
Clock
Square wave
Ground
Reset Pads
GND
EYE
DATA
CLK
ERROR
SQ.
WAVE
RESET
FPX20.0

*Exercise 1*

## Avoiding Aliased Displays to Speed Debugging

When debugging a circuit you may probe signals with widely varying repetition rates. If you move from a slow I/O signal to a faster clock or data line without changing your scope's time/division setting, the DSO is likely to produce an aliased display. Since the advent of DSOs, even experienced designers are occasionally misled by aliased waveforms that mask important data and lead the debug process in the wrong direction.

If your scope can display signals without aliasing, you won't lose information you need to keep debugging on track and moving quickly.

The following test will demonstrate your scope's ability to provide an information-rich non-aliased display:

### Test Setup:

1. Touch the probe to either side of the LED on the Waveform Generator Board.
2. Ground your probe at one of the GND connections on the board.
3. Press Autoset on your oscilloscope.

If you do not see a stable signal, set your scope as follows:

| Vertical Sensitivity | Time Base (sec/div) | Trigger |
|---|---|---|
| Ch1: 1 V/div | 40-50 ms/div | Slope: positive<br>Coupling: DC<br>Level: 3.5 V<br>Type: Edge<br>Mode: Normal |

## Test Results:

Compare your scope's display with this DSO's display (fig. 1) of the same waveform. The LED signal has a period of about 500 ms, and an on-time of 200 ms.

Without changing any settings, move your probe to one of the CLK or DATA signal pins. You should see a waveform similar to this (fig. 2). The result looks like a clock, but it has a much slower period than you might expect. This signal is aliased.

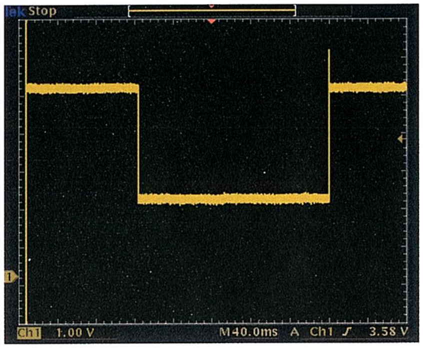



fig. 1
DSO

## DPO and Peak Detect

The period of the CLK signal is 2 µs (250,000 times faster than the LED). Aliasing of this higher frequency signal is due to undersampling by the DSO. To eliminate this problem you could decrease the time/division setting and thereby increase the sampling rate.

Even at slow time/division settings, DPOs maintain a higher sample rate than a typical DSO. A DPO is less likely to show aliasing than a typical DSO. If the scope that you are using has Peak Detect acquisition mode, turn it on now. Peak Detect will allow observation of both high frequency and low frequency signals without aliasing (fig. 3).

Using a DPO with Peak Detect helps you avoid aliasing. The color graded display on a DPO also allows you to see more detail in the waveform, even at slow time/division settings. Subtle details are seen in the DPO figure such as a DC level shift at the top of the waveform and a repetitive pattern in the waveform.

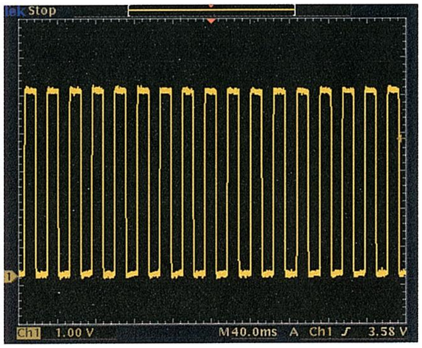



fig. 2
DSO

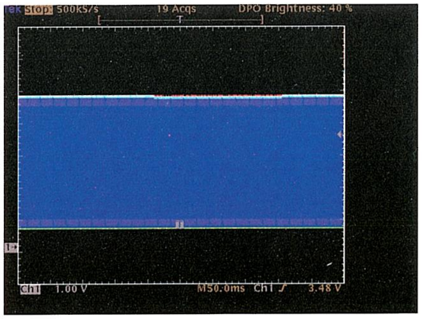



fig. 3
DPO

*Exercise 2*
# Identifying Setup and Hold Time Violations

Setup and hold time violations are common causes of failures in digital asynchronous systems. When a data signal does not remain stable for a long enough time, both before and after the leading clock edge, the driven device cannot determine the correct logic level. Faster clocks lead to tighter timing margins, and random phenomena such as noise and jitter can cause intermittent setup and hold violations.

Because finding these intermittent problems can require running thousands of data patterns through the system, and monitoring hundreds of data lines, you need an oscilloscope with a fast waveform capture rate.

## Test Setup:

1. Attach probe on Ch1 to the CLK pin; attach probe on Ch2 to the DATA pin.
2. Ground your probes at one of the GND connections.
3. Press Autoset on your scope.

If you do not see a stable signal, set your scope as follows:

| Vertical Sensitivity | Time Base (sec/div) | Trigger | Display |
|---|---|---|---|
| Ch1: 2 V/div<br>Ch2: 2 V/div | 500 ns/div | Type: Edge<br>Source: Ch1<br>Slope: negative<br>Coupling: DC<br>Level: 2.4 V | Infinite<br>Persistence<br>(if available) |

## Test Results:

### DSO

If you let your DSO capture the data and clock signals for 1 minute or so, you may or may not see a setup and hold violation near the active (falling) edge of the clock (fig. 1).

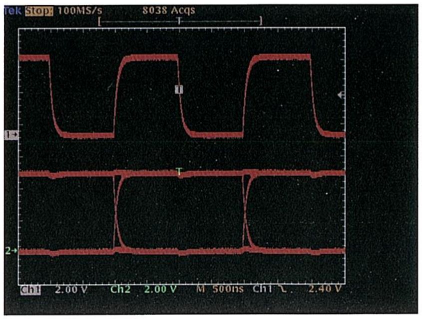



fig. 1
DSO

### DPO

With a DPO, the violations are identified in seconds. Notice the blue traces on Ch 2 (fig. 2).

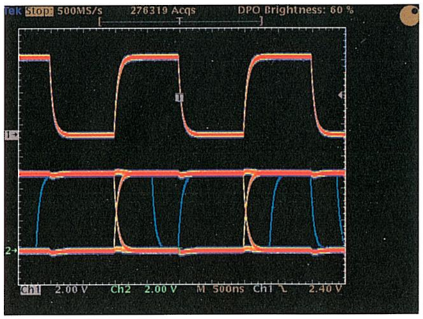



fig. 2
DPO

### Isolating Setup and Hold Violations

Once you have identified the pin on which the setup and hold violations are occurring, you can use a setup and hold trigger to capture the violations.

### Test Setup (requires setup and hold trigger):

Type: Logic
Class: setup and hold
Clock source: Ch1, level: 2.4 V, edge: negative
Data source: Ch2, level: 2.4 V
Setup time: 100 ns
Hold time: 102 ns
Mode: normal
When a setup or hold time violation occurs, you should see a display similar to this (fig. 3).

*Note: With a DSO, if you are unable to identify signal anomalies, you will never know how to set up advanced triggers to isolate the problem.*

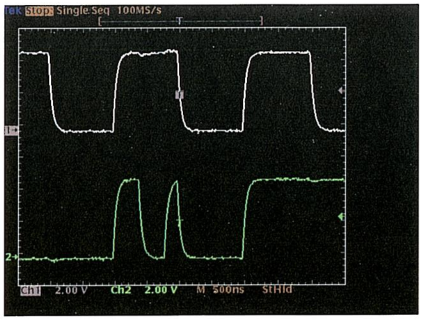



fig. 3
DSO

*Exercise 3*

# Debugging Intermittent Problems in Digital Circuits

Intermittent problems are the toughest to isolate, and frequently require you to look at several signals at once. This exercise simulates two devices driven by the same clock. One device's input is working perfectly; the other misses input data about once every million operations.

By the time the missed data is recognized, the cause of the event is past. The clock line on the second device could be corrupted, but exactly what the problem looks like and its probable cause are unknown.

This setup simulates checking the clock signal at two points on the board, and also a ground pin of the intermittent data buffer.

## Test Setup:

1. Attach the Ch1 probe to the CLK pin.
2. Attach the Ch2 probe to the SQ WAVE pin.
3. Contact the Ch3 probe to the solder pad below the LED and between the CLK and SQ WAVE pins.
4. Ground your probes at one of the GND connections.
5. Set the scope as follows:

| Vertical Sensitivity | Time Base (sec/div) | Trigger | Display |
|---|---|---|---|
| Ch1: 5 V/div | 500 ns/div | Type: Edge | Infinite or |
| Ch2: 5 V/div | | Source: Ch1 | variable |
| Ch3: 5 V/div | | Slope: positive | Persistence |
| | | Coupling: DC | (if available) |
| | | Level: 2.5 V | |

## Test Results:

### DSO

Using a DSO with persistence on, you may or may not capture the intermittent fault after waiting a minute or more. The DSO's slow waveform capture rate makes it easy to miss rare events without excessively long capture times (fig. 1).

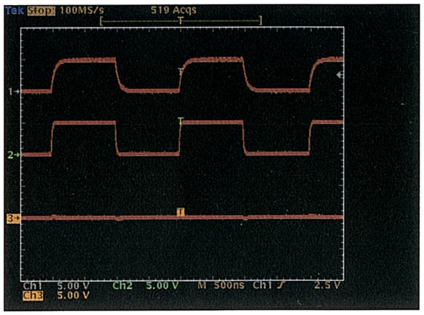



fig. 1
DSO

### DPO

Because the DPO's waveform capture rate is up to 1000 times faster than a typical DSO, the intermittent events are revealed almost immediately, even when observing multiple channels. With the problem identified, it can be further investigated using advanced triggering, such as runt triggering on the second clock signal or on the ground line.

This DPO display (fig. 2) shows that an invalid clock level occurred on the second clock signal (Ch2) when there was also a pulse on the buffer's ground line (Ch3). The simulated ground bounce on Ch3 might be the cause of the intermittent problem.

*Note: There are several intermittent events on these signals, you may see a different one than the one shown in figure 2.*

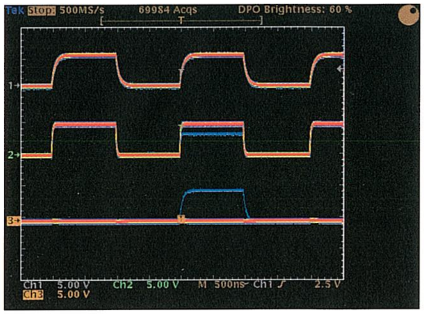



fig. 2
DPO

*Exercise 4*

## Data Communications Testing with Eye Diagrams

Communications system testing is particularly time consuming because systems must be tested using all possible data patterns. Because the number of data patterns is so great, and the time required to capture and observe them is so long, communications testing is often done using statistical processes.

Tests require triggering the oscilloscope on the system clock, and observing a data channel that is outputting pseudo-random data. The resulting composite waveform, called an eye diagram, shows the rise time, fall time, noise, ringing, duty cycle and other signal characteristics simultaneously.

The value and validity of the scope's measurements and statistics are proportional to how much data it can capture during the test period.

### Test Setup:

1. Remove the probes from the Waveform Generator Board.
2. Attach probe on Ch1 to the DATA pin.
3. Attach probe on Ch2 to the CLK pin.
4. Ground probes at one of the board's GND connections.
5. Set the scope as follows:

| Vertical | Time Base (sec/div) | Trigger | Display |
|---|---|---|---|
| Sensitivity<br>Ch1: 1V/div<br>Position Ch1:<br>-2 divisions | 500 ns/div | Type: Edge<br>Source: Ch2<br>Slope: negative<br>Coupling: DC<br>Level: 2.5 V | Ch2 off (used for trigger source only)<br>Infinite Persistence (if available) |

Let your DSO capture data for about 1 minute and then stop the acquisition.

## Test Results:

### DSO

One minute of accumulation on a typical DSO produces approximately 4,800 acquisitions. After an hour it would collect almost 300,000 acquisitions. This waveform count may or may not be sufficient for your test statistics, but waiting an hour for each test may not be practical (fig. 1).

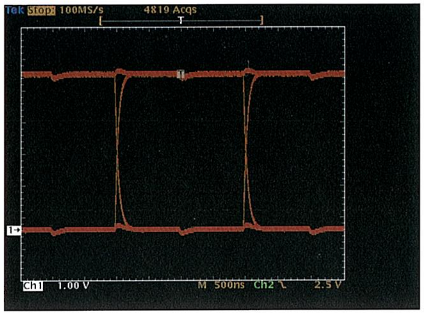



fig. 1
DSO

### DPO

After just *10 seconds* of accumulation, this DPO produced over 400,000 acquisitions (fig. 2). In addition, the DPO's color or intensity graded display reveals occasional data patterns in this signal that occur very infrequently (dark blue lines). The DSO's slow capture rate never saw these occasional patterns. The DPO's fast waveform capture rate produces greatly superior statistical results no matter how long you wait.

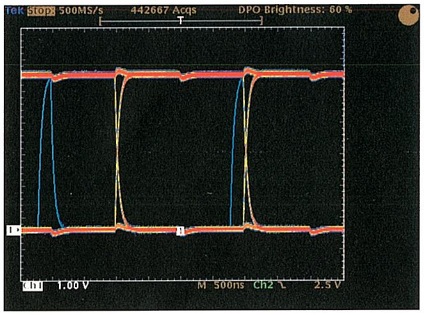



fig. 2
DPO

*Exercise 5*

## Measuring Jitter on Serial Data

Characterizing jitter in a communications system often must be made on transmitted data streams without benefit of a complete receiver with clock recovery. An oscilloscope can make these measurements by triggering on the data channel and delaying by a few data bits. The jitter measurement is made on the delayed portion of the data stream relative to the trigger point.

Jitter characterization is time consuming because of the vast number of data patterns that must be tested, and because some jitter sources are intermittent. Ideally, data is collected for a period of time, and statistics are used to analyze the nature of the jitter.

### Test Setup:

1. Attach probe on Ch1 to the DATA pin.
2. Ground your probe at one of the board's GND connections.
3. Set your scope as follows:

| Vertical | Horizontal | Trigger | Display |
|---|---|---|---|
| Sensitivity Ch1:1 V/div Position Ch1: -2 divisions | Time Base:100 ns/div Delay: ~6 μS after the trigger point to see the eye crossing of the random data, 3 symbols after the trigger. | Type: Edge Source: Ch1 Slope: positive Coupling: DC Level: 2.4 V | Infinite Persistence (if available) |

Let your oscilloscope capture data for about 1 minute and then stop the acquisition.

## Test Results:

After capturing several thousand data patterns, the width of the eye crossing measures the peak to peak jitter. Advanced scope analysis features such as histograms and histogram measurements let you see qualitatively and statistically how the edges of the data waveform vary with time. (The thin blue box on these figures is the voltage window used to determine the values for the time histogram.)

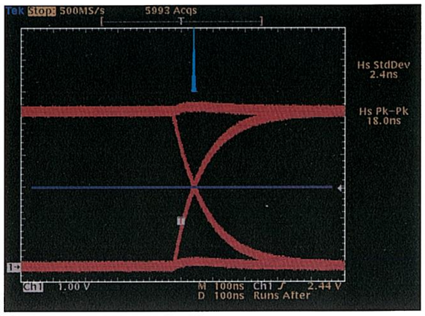



fig. 1
DSO

## DSO

This DSO shows the results of collecting data for approximately one minute (fig. 1). A histogram measures the jitter at the data crossing point. Notice the peak-to-peak jitter and standard deviation measurements differ by less than 20 ns.

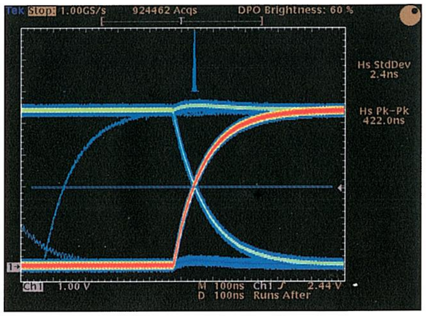


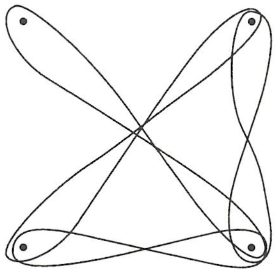

fig. 2
DPO

## DPO

Because of the vastly greater number of waveforms it captures, the DPO reveals rare jitter events that increase the peak-to-peak jitter measurement to 400 ns (fig. 2). Further, the DPO's color graded display helps view the relative frequency of occurrence between events, and highlights rare jitter events (blue trace).

*Exercise 6*

## Troubleshooting with X vs. Y Displays



Certain designs are best characterized using a scope's X vs. Y display mode. One example is In-phase (I) and Quadrature (Q) components of a complex modulated RF signal. This X-Y display is often called a vector diagram, as it allows viewing of phase and amplitude relationships of the modulation.

In an X-Y display, the four distinct locations (symbols) where the signal dwells are easy to see. The receiver uses a symbol clock synchronized with the four symbol locations to determine the data values. Ideally, the four symbol points should form a perfect square.

Any deviation can indicate distortion in the modulation. In addition, by observing the transitions between symbols you can determine if proper filtering is used and if there are interfering signals.

### Test Setup:

1. Remove the probes from the Waveform Generator Board.
2. Attach probe on Ch1 to the CLK pin.
3. Attach probe on Ch2 to the DATA pin.
4. Ground probe at one of the GND connections.
5. Press Autoset on your scope.
6. After Autoset has created a stable voltage and time display, make the following adjustments to the scope settings:

| **Vertical** | **Display** |
|---|---|
| Sensitivity Ch1 and Ch2: 1 V/div<br>Position Ch1 and Ch2: -2 divisions | XY mode,<br>Infinite or variable persistence on (if available) |

## Test Results:

### DSO

In this DSO display (fig. 1) it is possible to see how the I and Q signals transition between and dwell at each symbol point. However, frequency of occurrence for each point in the vector diagram cannot be determined. The density of the data is so small that the display looks flat.

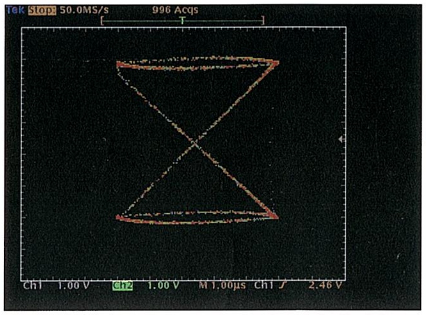



fig. 1
DSO

### DPO

This I and Q display (fig. 2) offers much more information. The DPO's color or intensity graded display lets you see the probability and frequency of occurrence of various parts of the signal. Notice the brighter red spots in the figure at each symbol point. Also notice the less frequent vertical transitions that do not appear on the DSO. The 3-D appearance is rich in information.

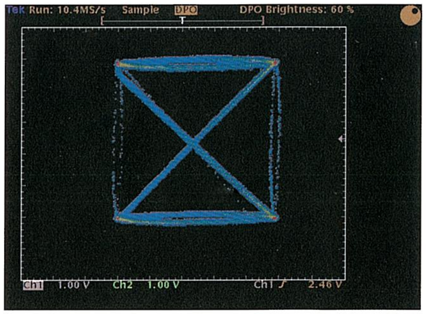



fig. 2
DPO

## Thank You.

We hope that you have found this Scope Evaluation Kit both useful and informative. At Tektronix we are committed to providing you with the most advanced measurement equipment to help with your most complex design requirements.

Please feel free to share this kit with your colleagues. If we can be of further assistance to you, please contact your nearest Tektronix sales office, visit us on the web, or return the enclosed reply card.