

Ten Measurements

(you didn't think you could make)
with an Oscilloscope



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Instrumentation & Measurement Society

Telephonics

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Tektronix FAE

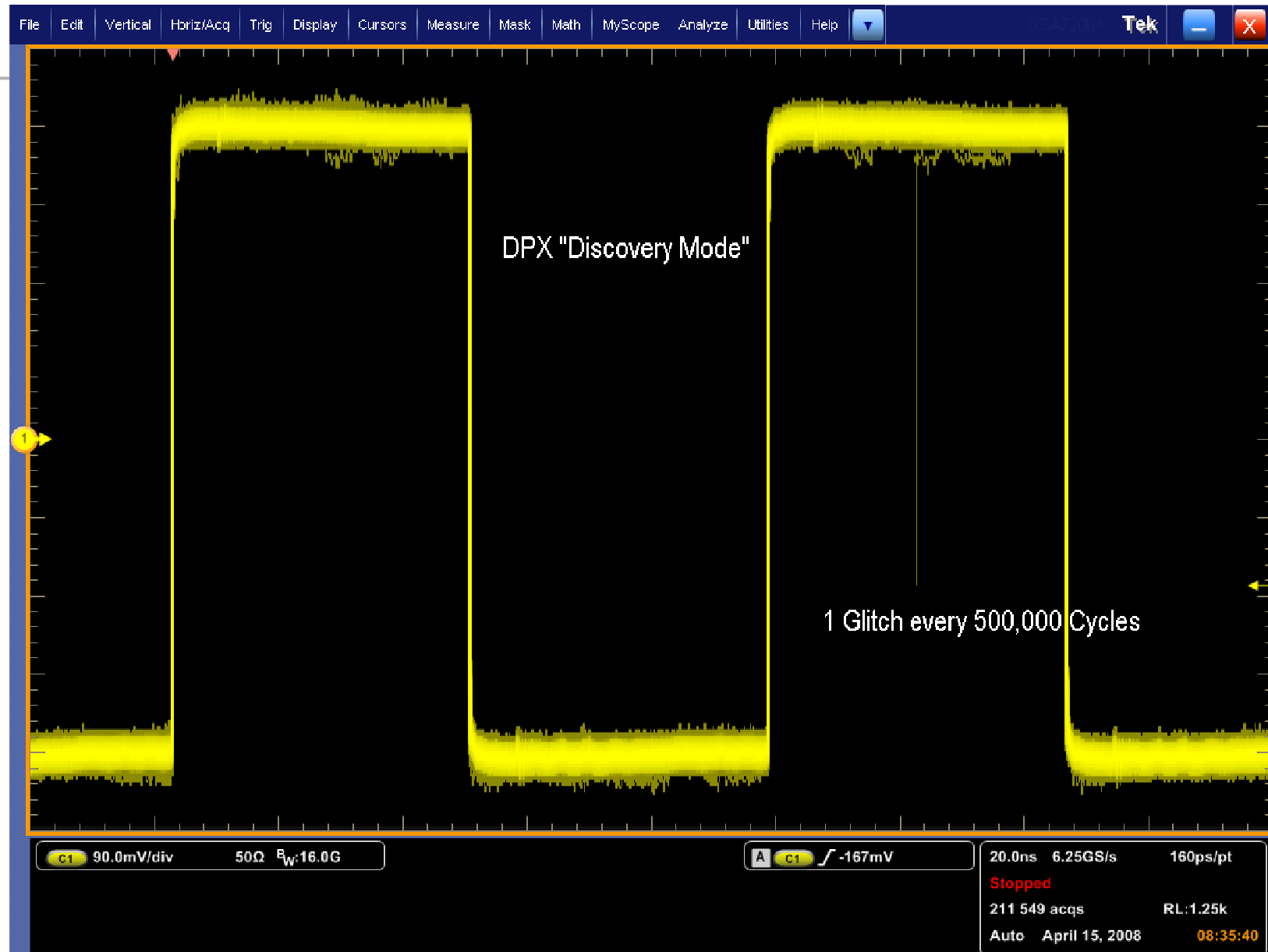
Agenda

- ▶ Playing the odds with intermittent faults...
- ▶ Rolling with the punches...
- ▶ Turn down that noise!
- ▶ Getting turned on: vertical bits
- ▶ Probe magic
- ▶ Triggering in 3D
- ▶ There's a secretary in my scope
- ▶ One bad bit spoils the whole bunch
- ▶ Punctuality is a virtue
- ▶ But will it work?

Playing the odds with intermittent faults

- ▶ Let's say you have a circuit that's failing intermittently.
- ▶ You need to probe several signals and try to find the problem
 - You know what the signals are supposed to look like. But you don't know which signal is failing. Or what the failure looks like
- ▶ You need a scope with fast update rate, and display persistence, to DISCOVER the problem
- ▶ Then you'd like to be able to TRIGGER on the problem.
- ▶ Then you can MEASURE the problem.

DPX Discover Mode: Simple Edge Trigger



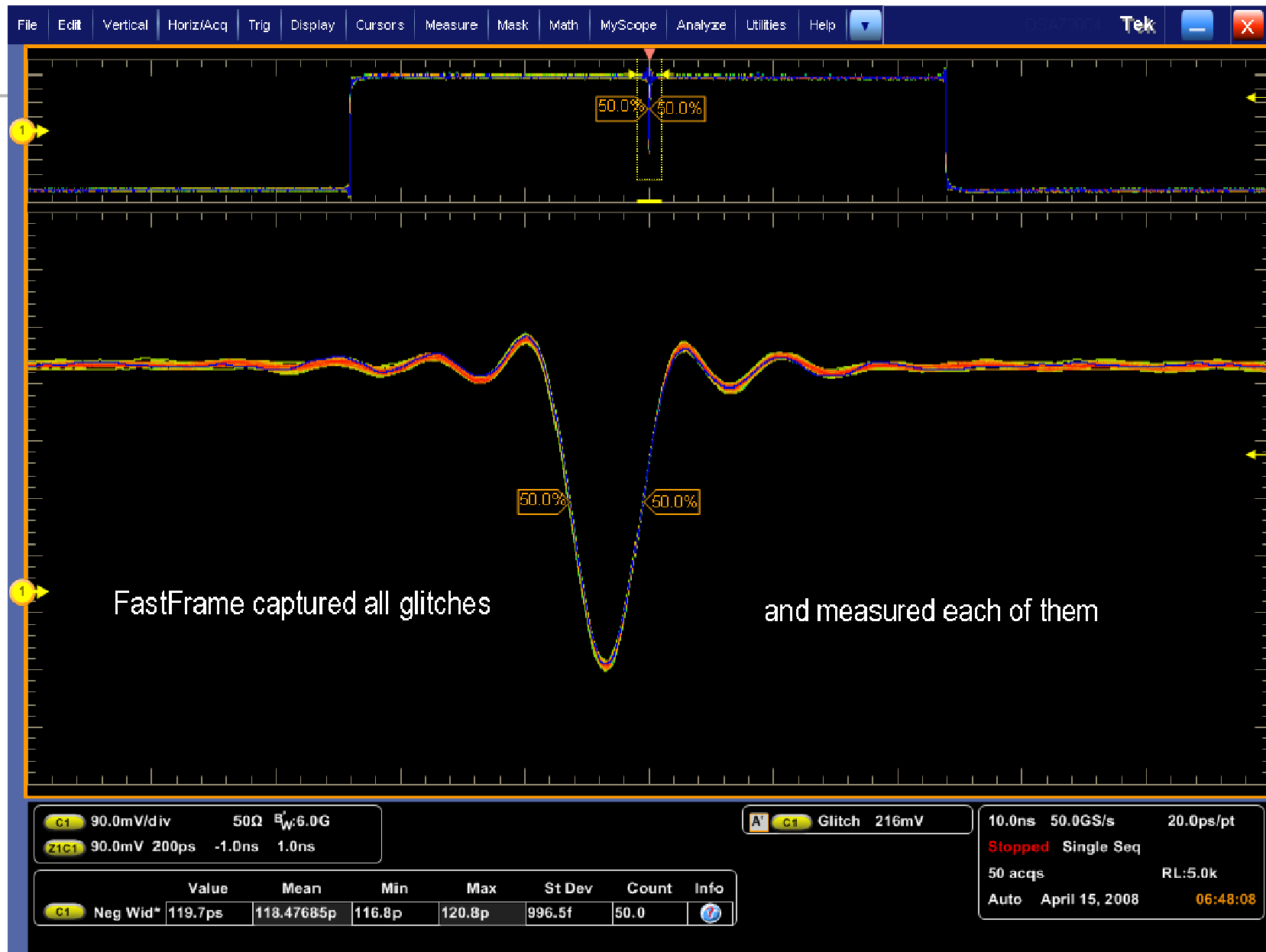
DPX: > 5 billion acquisitions in 7 hours



Glitch Trigger



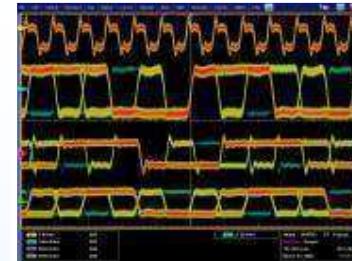
FastFrame



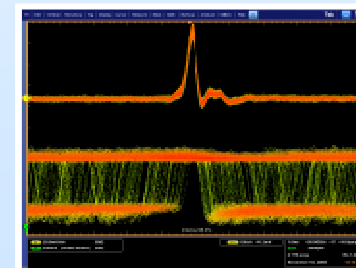
Real-Time DPO: Unequaled Debug Power

- ▶ DPO FastAcq at all real-time Sample Rates
 - Powerful, efficient debug capability for quickly identifying and isolating anomalies
- ▶ Captures thousands of acquisitions in seconds rather than minutes or hours
 - Identifies rare anomalies or subtle patterns
 - Waveform Capture Rates >300,000 waveforms/s
 - Operates simultaneously on all channels
 - Ideal for debug across multi-lanes of serial data

Real Time DPO



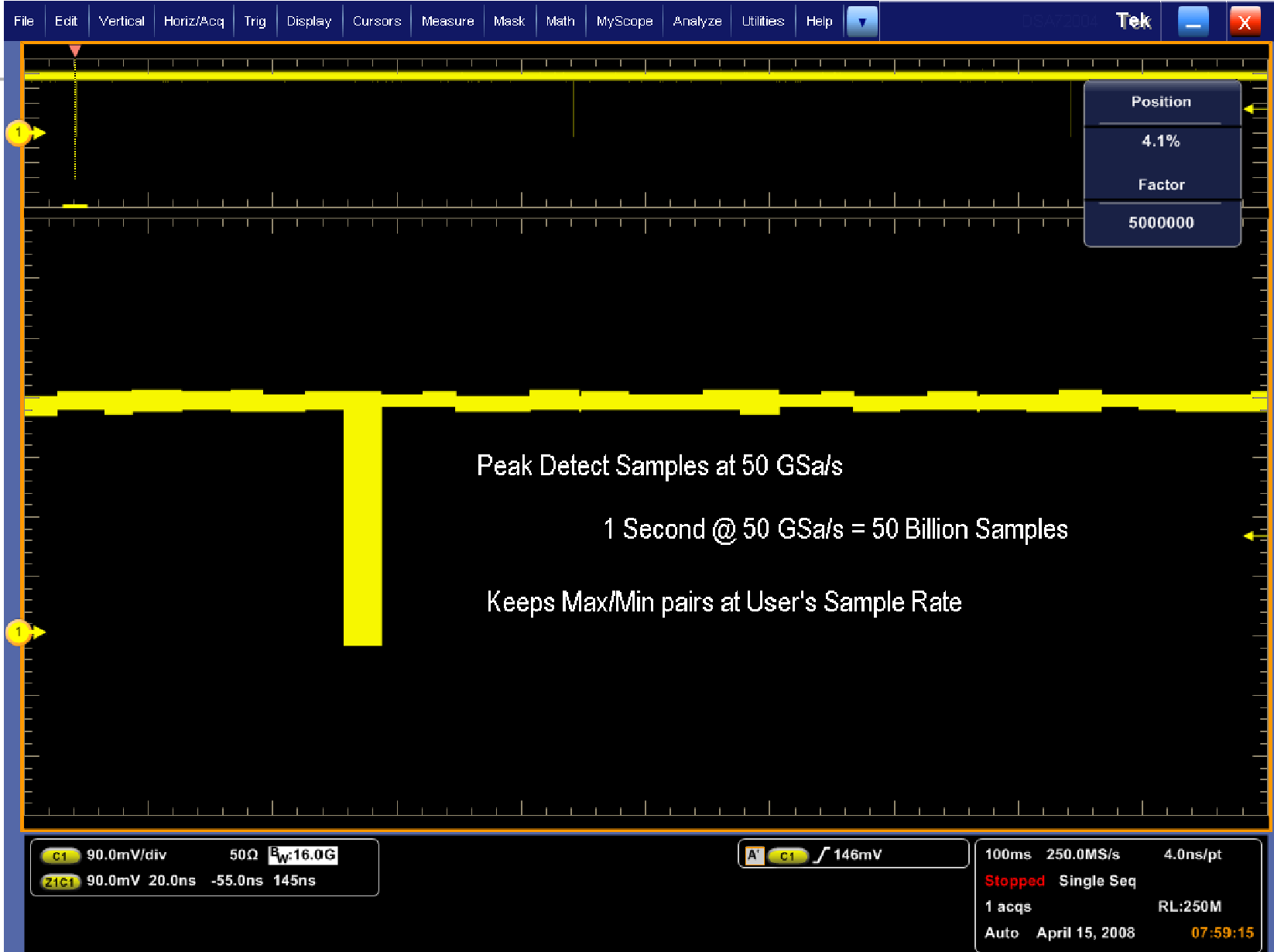
- ▶ Real-time acquisition
- ▶ Long record length
- ▶ Fast waveform capture rates
- ▶ Intensity & persistence displays



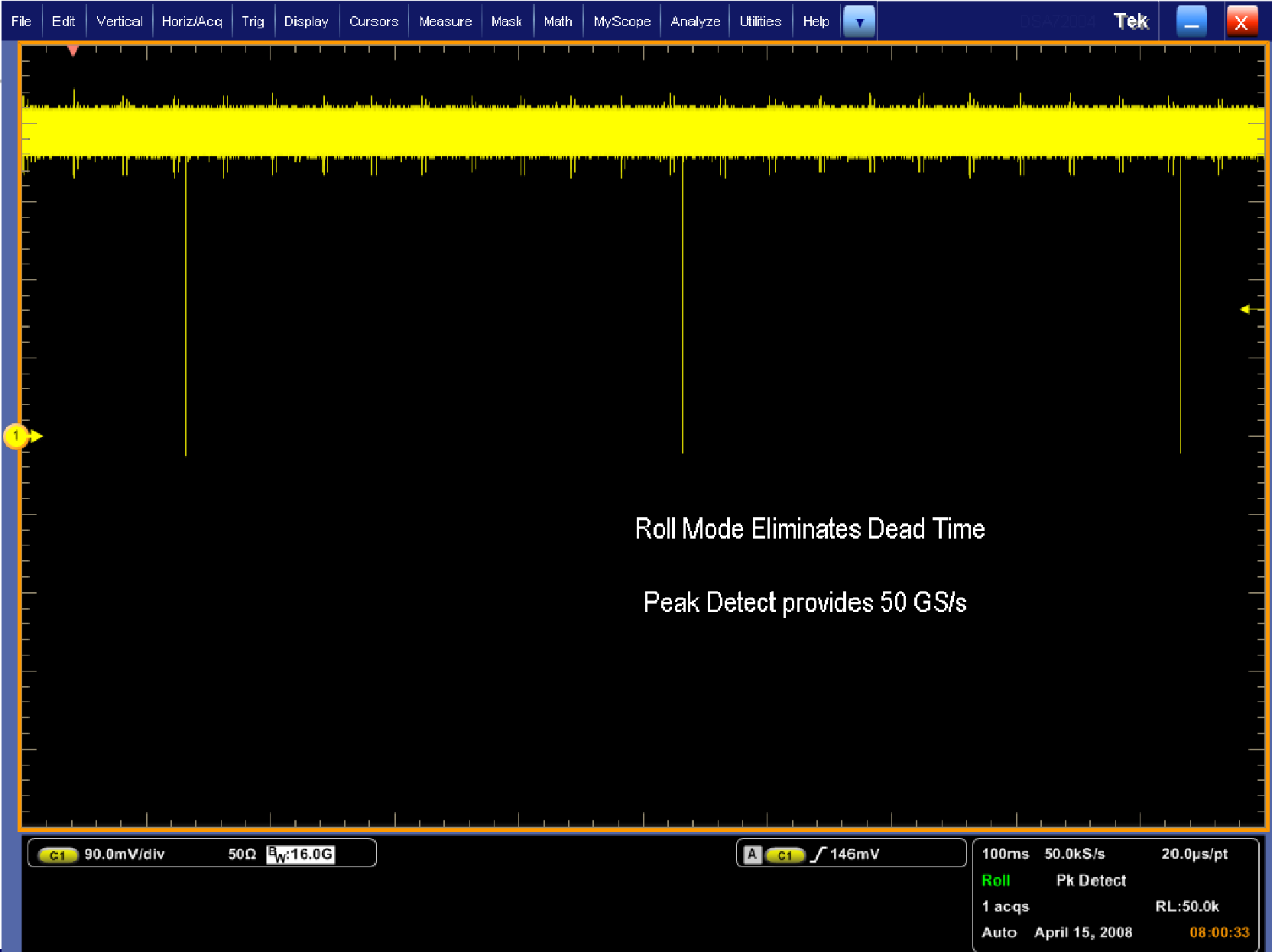
Rolling with the punches...

- ▶ Let's say you'd like to monitor a power supply, looking for glitches, sags, drop outs. You'd like to monitor for say, one second.
- ▶ You can use Peak Detect to maintain max sample rate even at very slow sweep speeds.
- ▶ You can use Roll mode to eliminate dead time.
- ▶ You can use Template Test to automatically capture, save, email...

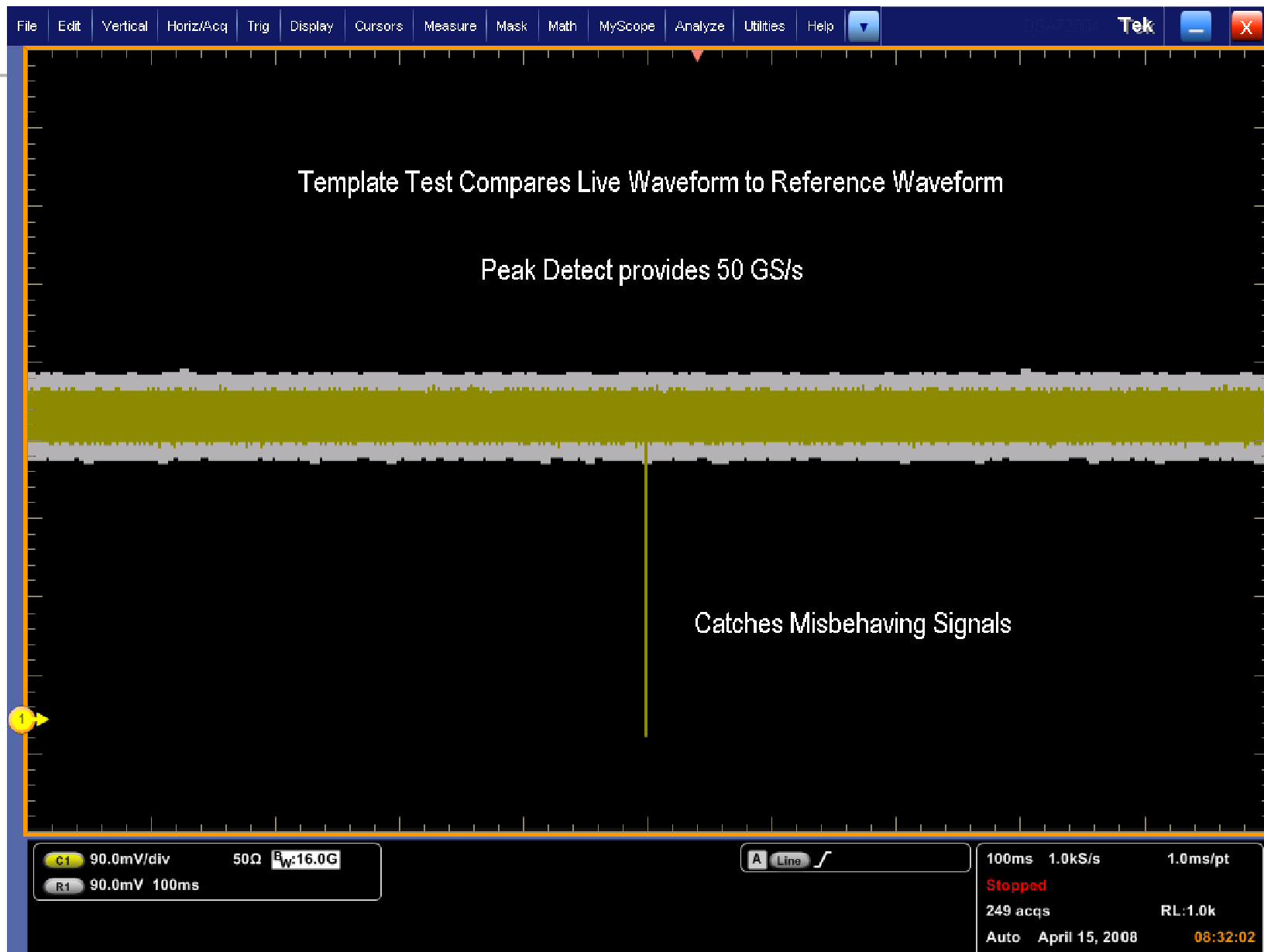
Peak Detect: 50 GS/s at any sweep speed



Roll Mode



Template Test



Turn down that noise!

- ▶ Noise is proportional to $kBTr$
- ▶ The more BW a scope has, the higher the noise
- ▶ There is such a thing as *too much* BW
- ▶ Ultra high performance scopes often have more BW than needed

- ▶ Techniques for reducing noise:
 - Run self-calibration (SPC)
 - Vertical BW Limit (DSP)
 - Signal Averaging on repetitive signals
 - Hi Res on repetitive or single shot signals
 - Math filter function

BW Limit – per channel



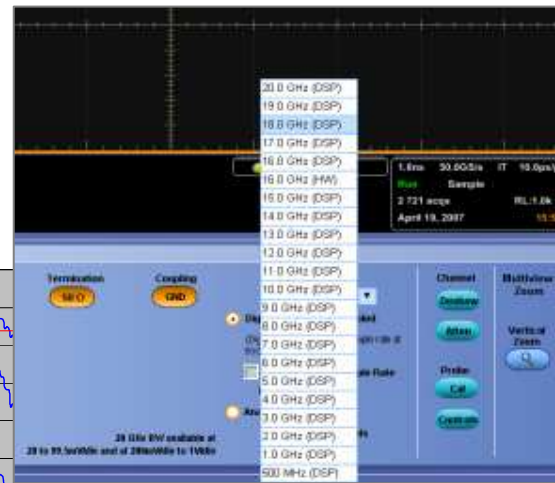
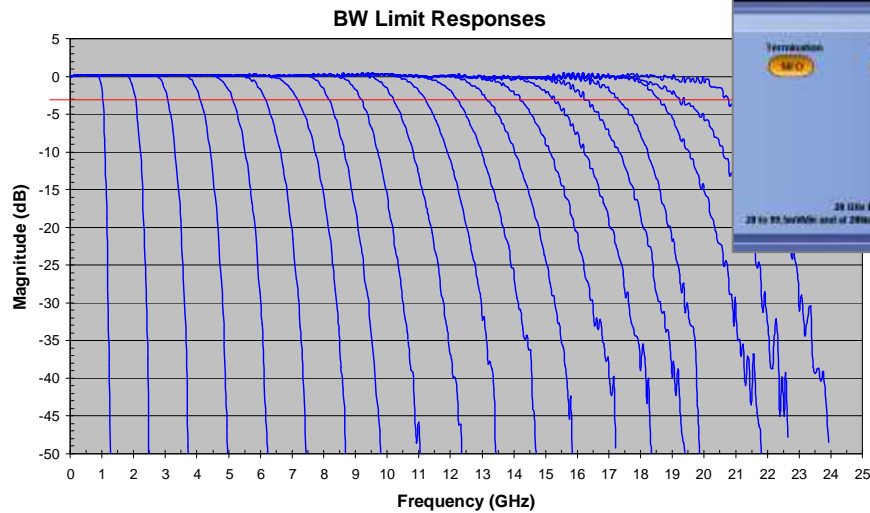
True signal fidelity

▶ **Bandwidth Limit Selection**

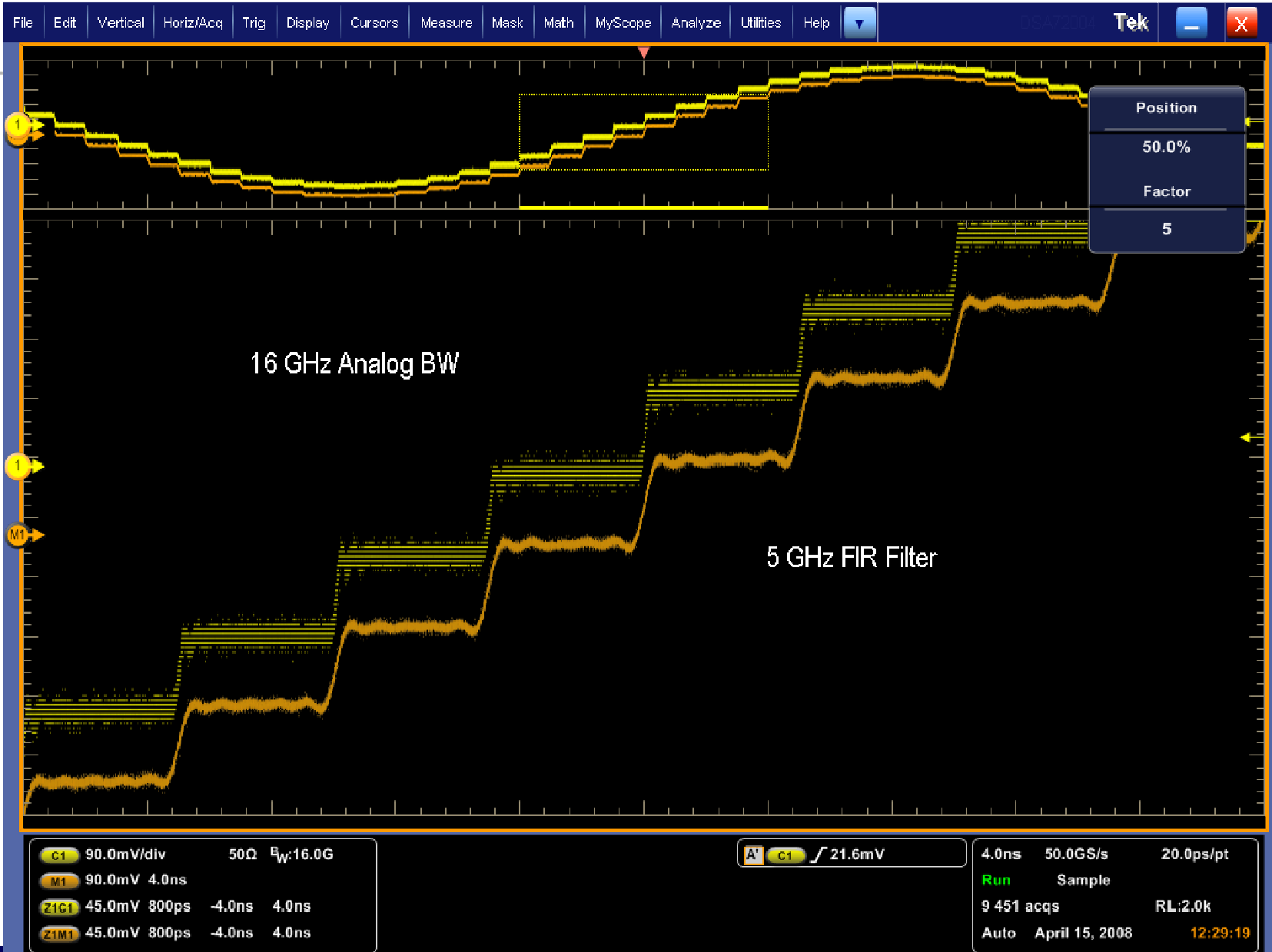
- True fidelity with performance scaled to the job
- Remove unwanted signal content to show actual circuit operation

▶ **BW Enhancement to the probe tip**

- Clean signals, high fidelity with the best probes available
- Optimize performance for the exact scope/probe/tip

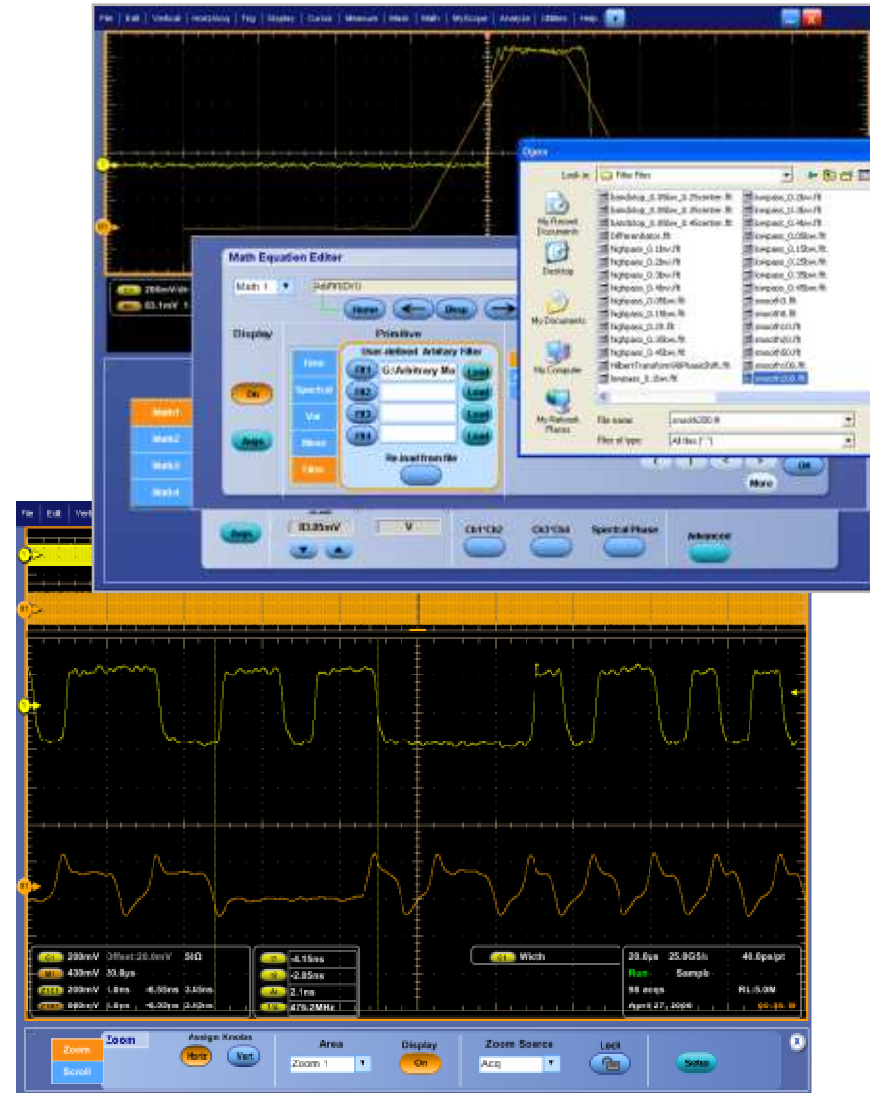


FIR Filter Function



User-definable FIR filtering

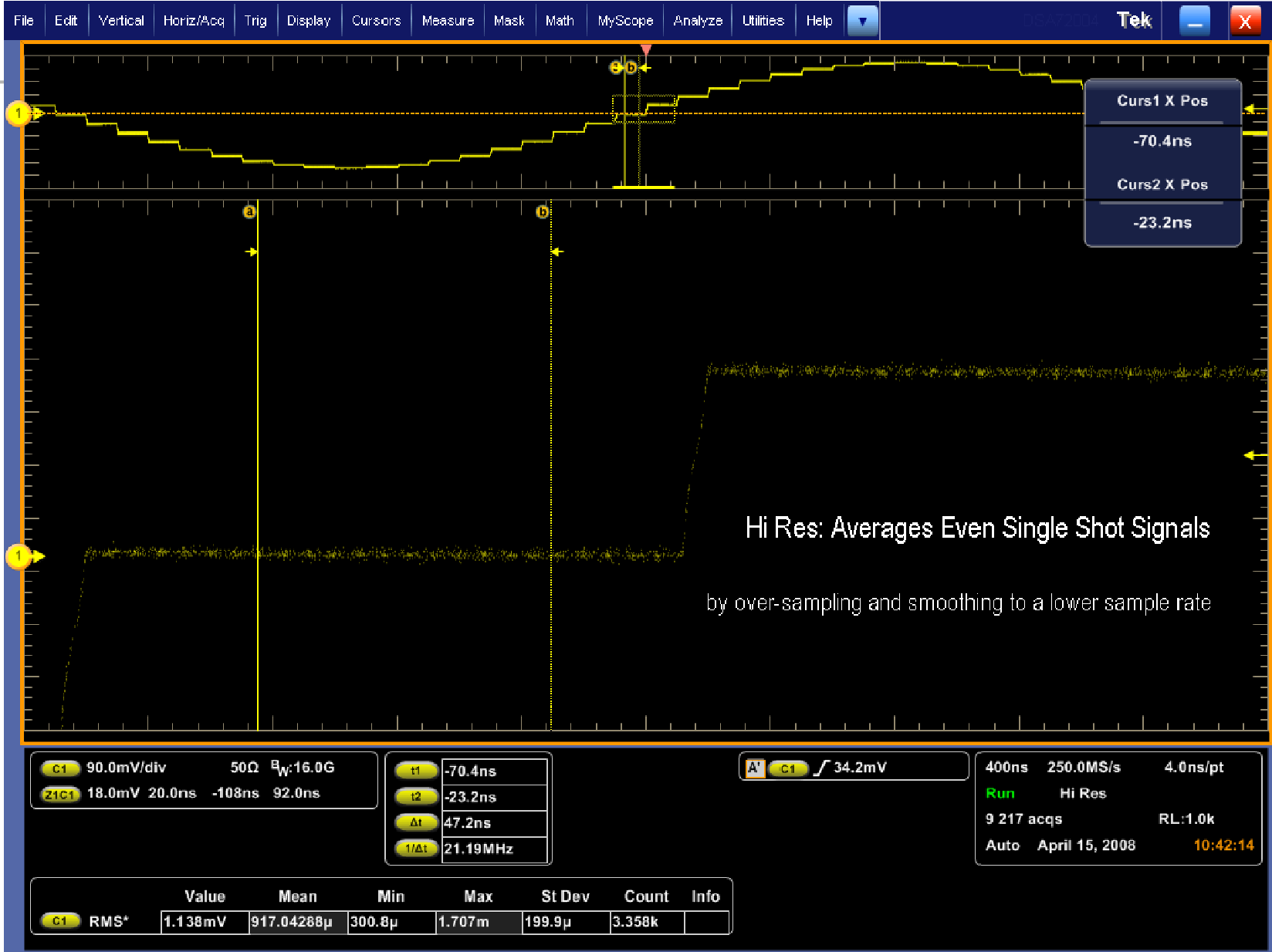
- ▶ Apply your own custom designed FIR filters
- ▶ Apply your proprietary Serial Data deconvolution or equalization filters
- ▶ Library of general purpose FIR filters provided
 - Low pass
 - High pass
 - Band pass
 - Band stop
 - Smoothing or box car
 - Hilbert Transform
 - Differentiator



Getting turned on: vertical bits

- ▶ High BW scopes have 8 bits of resolution
- ▶ Well actually, some of those bits are noise, especially at higher frequencies
- ▶ ENOB, Effective Number Of Bits
 - SNR expressed in bits
 - Tested with pure sine waves, over the scope BW
 - Table of values: ENOB @ frequency
 - DSA70000 series achieves best in class ENOB
- ▶ Methods to achieve higher vertical resolution:
 - Sweep averaging, on repetitive signals
 - Hi Res mode, even on single shot signals
 - Vertical Offset *and* Position

Hi-Res Acquisition Mode



Full suite of acquisition modes

How the Acquisition Modes Work

Sample mode retains one sampled point from each acquisition interval.

Waveform Database mode takes an ensemble of acquisitions that is best for accurate eye pattern measurements.

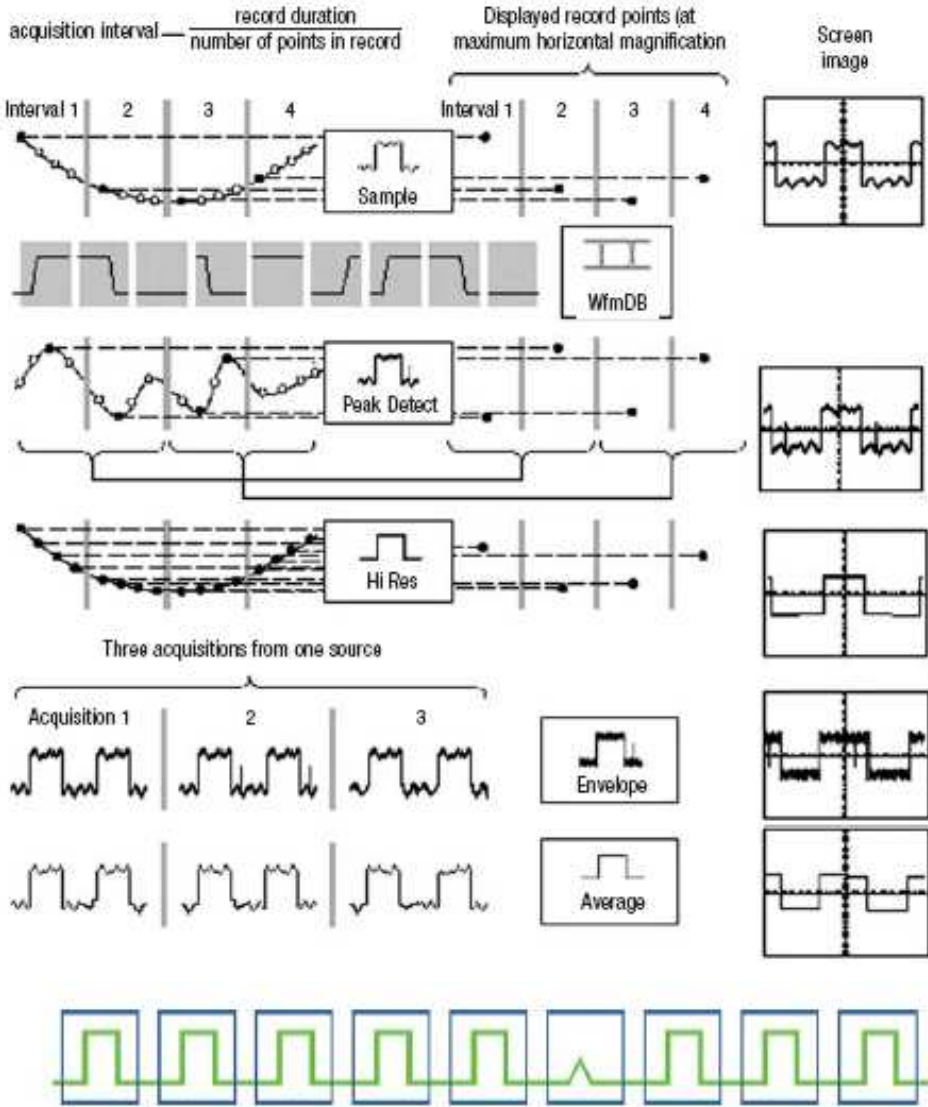
Peak Detect mode uses the highest and lowest of all the samples contained in two consecutive acquisition intervals.

Hi Res mode calculates the average of all the samples for each acquisition interval.

Envelope mode finds highest and lowest record points over many acquisitions. Envelope uses Peak Detect for each individual acquisition.

Average mode calculates the average value for each record point over many acquisitions. Average uses Sample mode for each individual acquisition.

FastAcq mode continuously acquires up to 400,000 wfms/s minimizing the blind-time between acquisitions.



Full suite: basic acquisition tools

- ▶ Sample mode – normal oscilloscope operation
 - Workhorse for most signals
- ▶ Average mode – average multiple acquired waveforms
 - Reduce random noise, stabilize measurements
- ▶ Envelope mode – show the max/min at each waveform point
 - See signal excursions over time
- ▶ Hi Res mode – average between sample points
 - Uses full sample rate at slower time/div to average-out noise
 - Average within each acquisition to reveal signal from noise
 - Works on non-repetitive signals
 - Acts as bandwidth filter
- ▶ Peak Detect mode – keeps max/min at each point
 - Find fast glitches even at slow time/div settings
 - Maximum time resolution even for slow events

Full suite: advanced acquisition tools

- ▶ **Waveform Database mode – 3-d waveform storage**
 - Database of acquired points over time
 - ▶ Amplitude vs. Time plus frequency of occurrence information
 - Basis for advanced measurements, compliance testing
 - ▶ Eye diagram measurements
 - Rapidly acquires lots of waveform data
- ▶ **FastAcq mode – super-fast acquisitions with minimum dead time**
 - Best troubleshooting tool, minimize debugging time
 - Quickly reveals infrequently occurring events, states, errors
 - Shows dynamic signal changes as they occur
- ▶ **FastFrame mode – capture multiple trigger events in one record**
 - Efficient memory use for multiple events with dead time between
 - Short rearm time for fast events occurring rapidly
 - ▶ Repetitive capture of pulses (radar, laser, etc.)

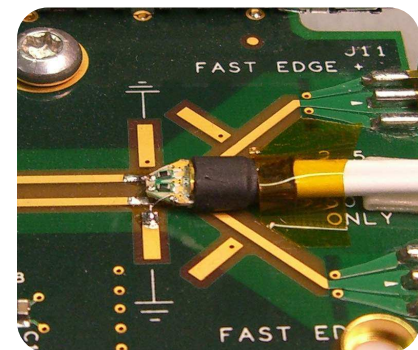
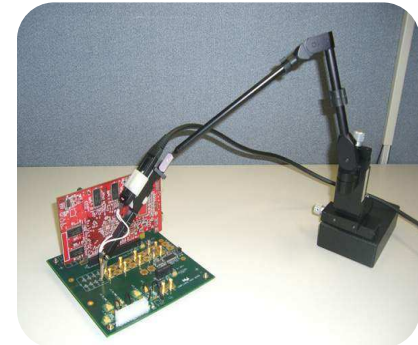
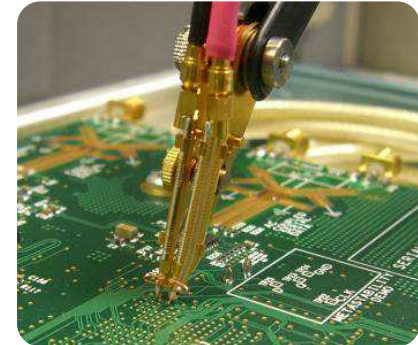
Probe magic

- ▶ If you can't probe your signal, your scope is useless
- ▶ High Performance Scopes need High Performance Probes
 - Sometimes the probe is “the tail that wags the dog”
- ▶ High BW Scopes are 50 ohm input
 - Need an amplifier to use a 10x passive probe (500 MHz)
 - Active Probes needed above 500 MHz
- ▶ Z-Active Probes are a new class of probes
 - Blend of passive 50 ohm probe and Active probe
- ▶ Tri-Mode probes make diff and single ended measurements
- ▶ The world's fastest probe: P7520, 20 GHz
 - Solder in
 - Hand held, with adjustable tips!

DUT Connection

When to use a probe?

- ▶ Typically used when a signal needs to be measured and no SMA or RF connector is available
- ▶ Debug
 - Require a quick way to check that signals are present
 - Handheld probing offers the best versatility
 - Solder tips can be used for a more permanent connection for troubleshooting
- ▶ Validation and Compliance Testing
 - Chip to chip buses
 - Small solder tips are ideal for attaching to small features and give a permanent hands free connection to the signal
 - Fixtured probes can be used when soldering to a board is problematic



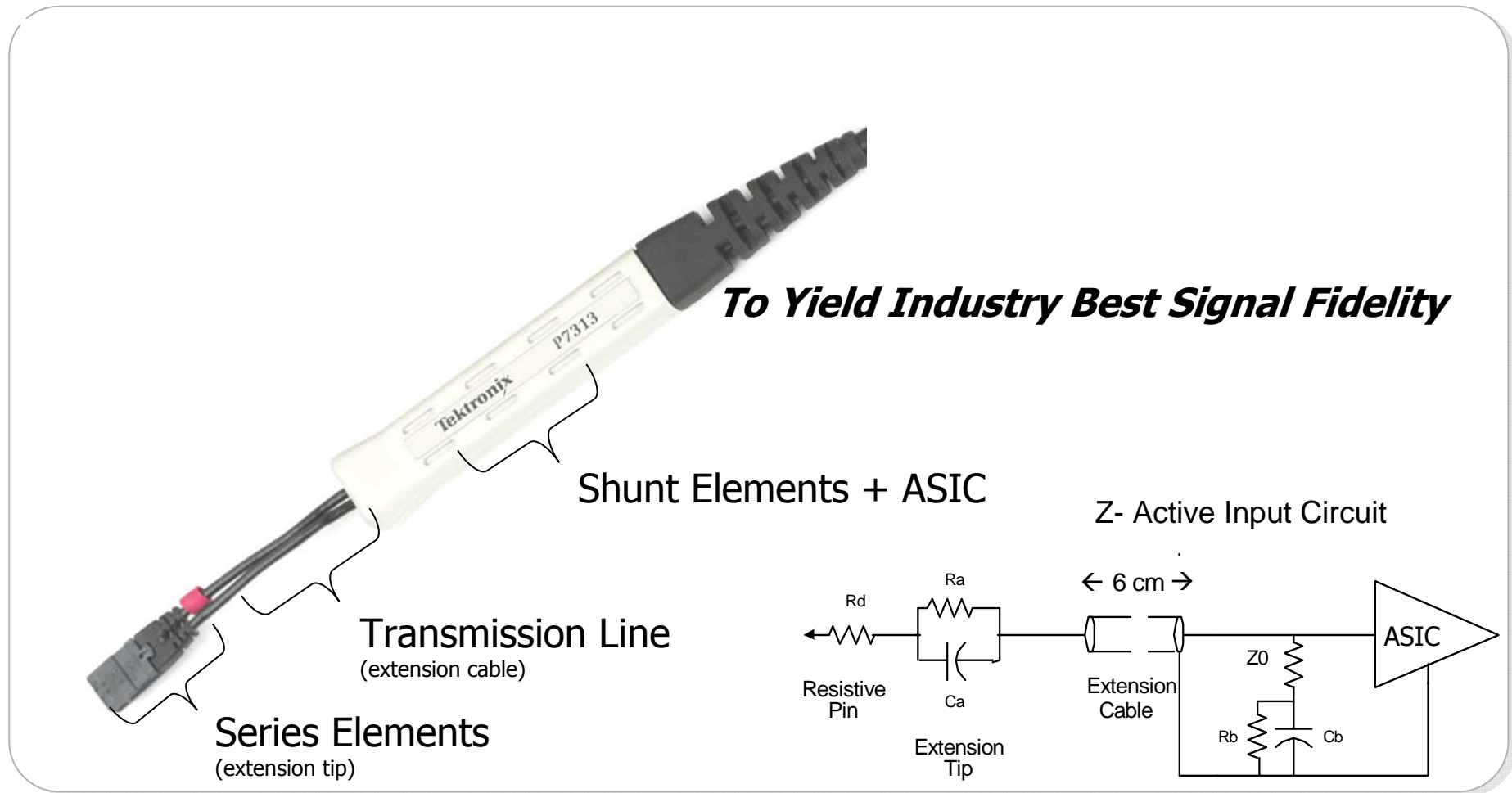
P73xx Z-Active Differential Probe Family

- ▶ **Z-Active™ architecture**
 - High bandwidth and fast rise time
 - Flat step response
 - Low loading
- ▶ **Built for usability**
 - Small probe head
 - Switchable Gain for extended dynamic range
- ▶ **Versatile Tip-Clip™ adapter connections**
 - Solder-In
 - Handheld
 - Fixtured
 - Low Cost-of-Ownership over many connections
- ▶ **P7340A: 4 GHz**
- ▶ **P7360A: 6 GHz**
- ▶ **P7380A: 8 GHz**
- ▶ **P7313: 13 GHz**



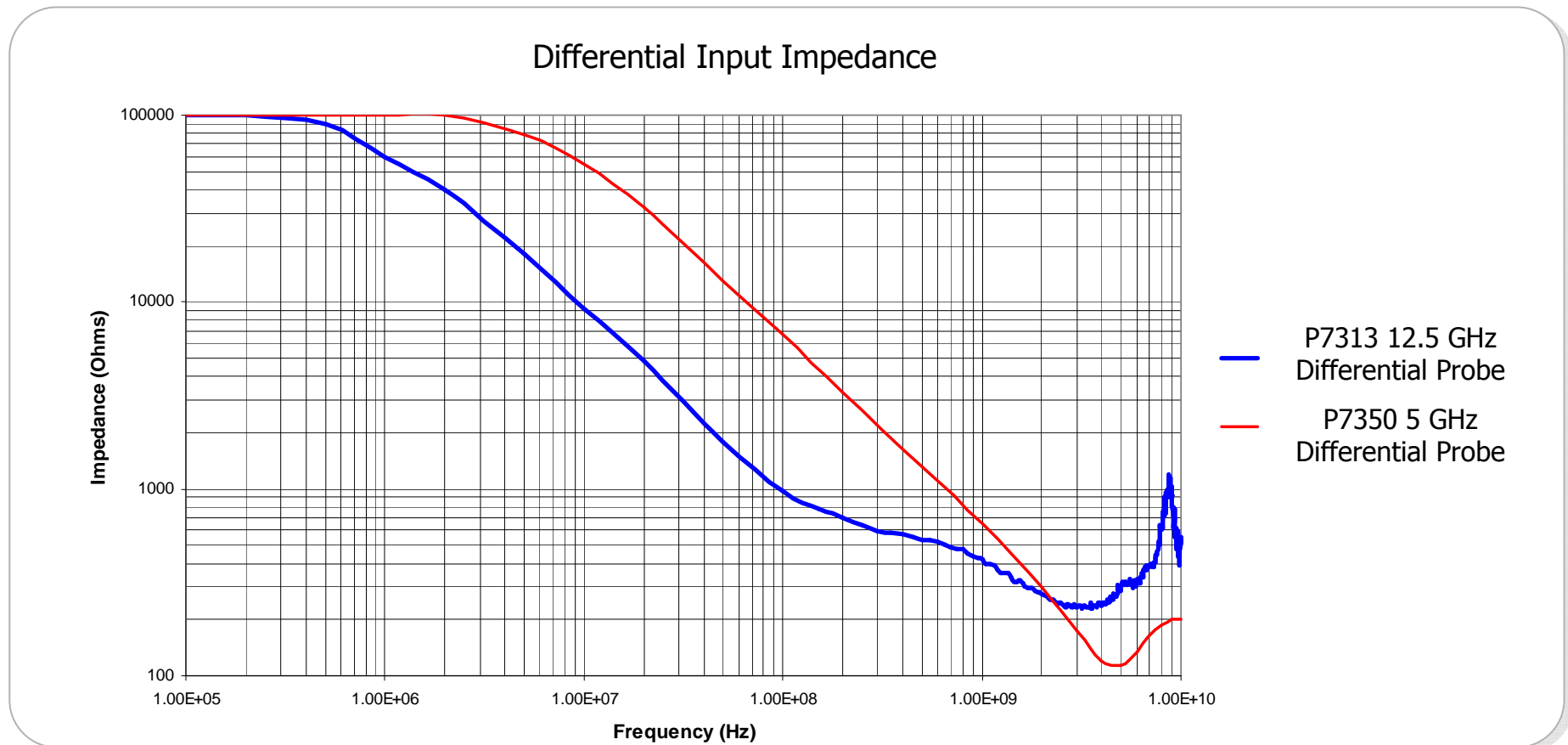
Z-Active Architecture

Combines Active and Passive Design Elements



Z-Active Architecture: Low DUT Loading

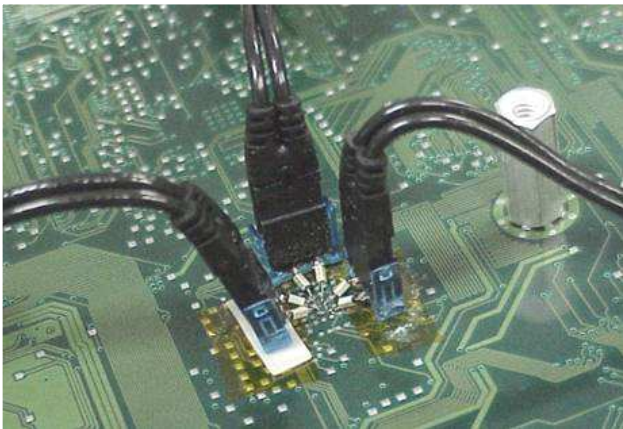
- ▶ Industry's lowest loading
 - High DC resistance like an "active" probe
 - High, stable input impedance at high frequencies like a " Z_0 " (passive) probe



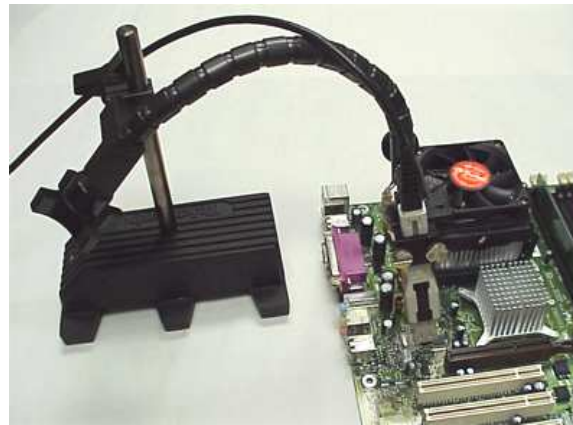
P7313 Connectivity Benefits

- ▶ Tip-Clip™ assemblies - An interchangeable probe tip system that enables customers to configure their probe with the optimal tip for their application.

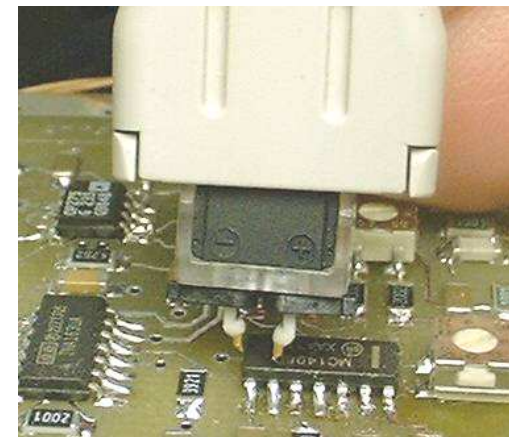
-- Solder-in Solutions



-- Fixtured Solutions



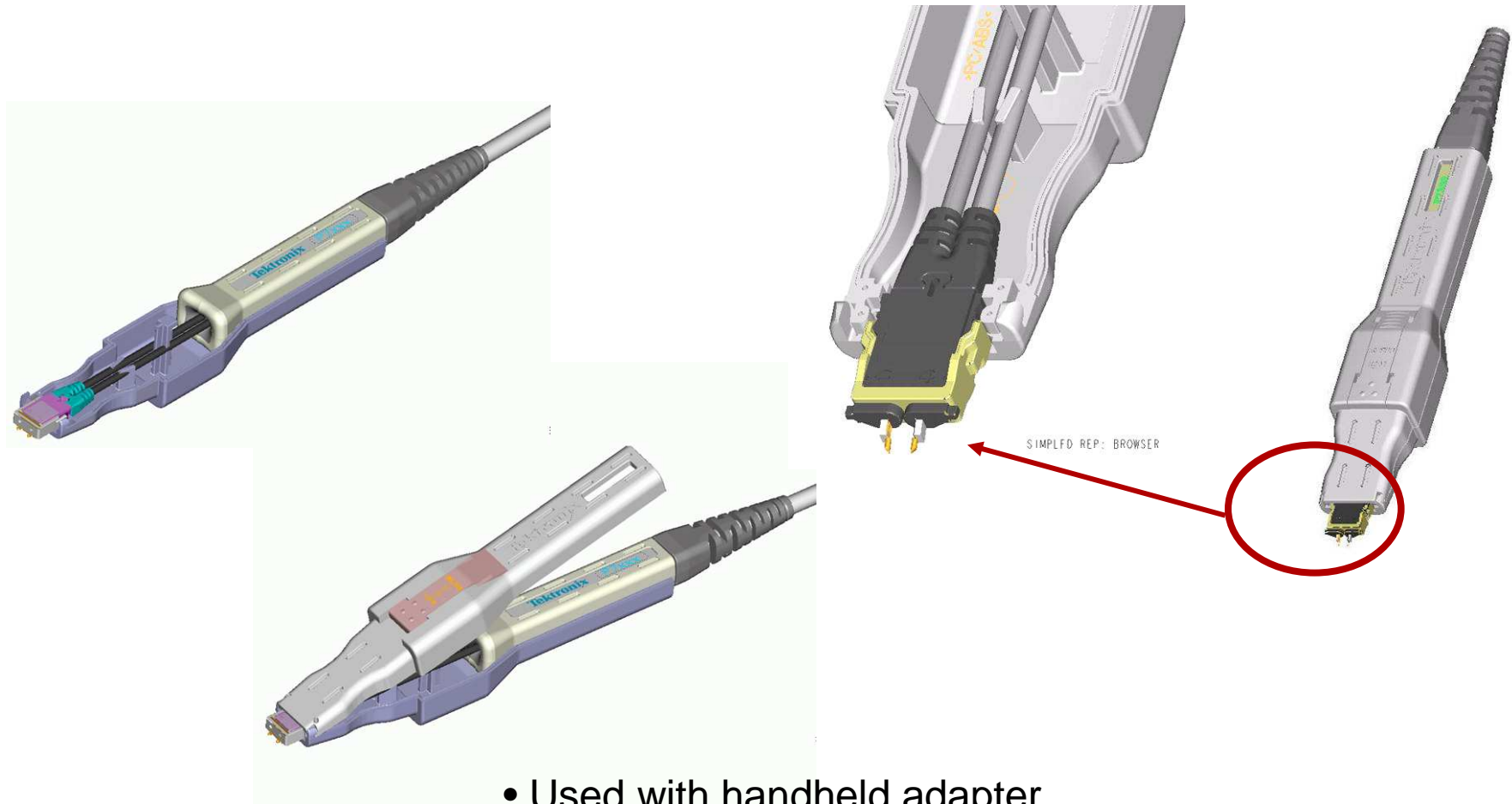
-- Handheld Solutions



- ▶ Variety of Tip-Clip™ assemblies
 - Application specific
 - Can introduce new connectivity solutions without having to redesign the probe.



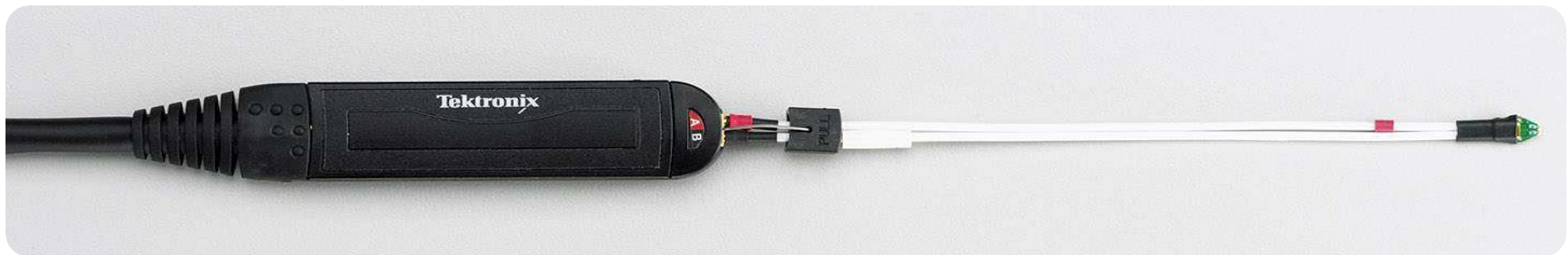
Handheld Probing Handheld Adapter



- Used with handheld adapter
- Provides variable spacing
- Provides vertical compliance (spring force) – self-leveling

TriMode™ Probe Family P7500 Series

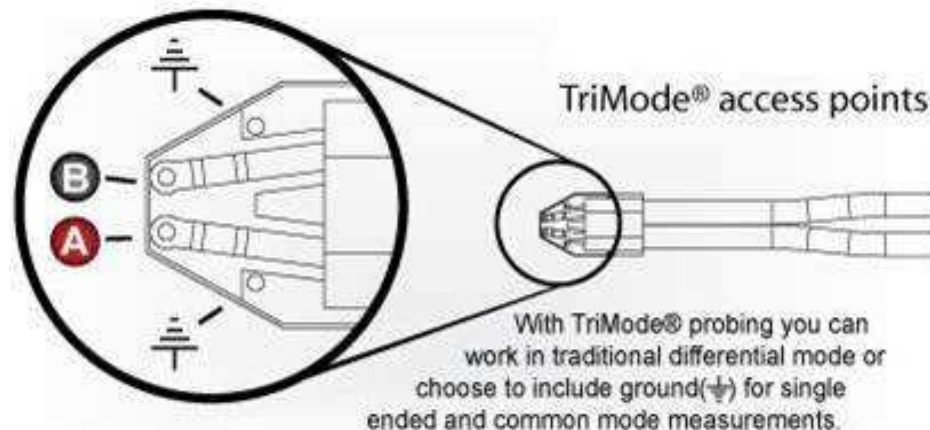
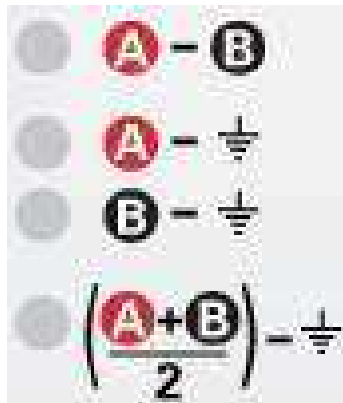
- ▶ Performance
 - 13 GHz, 16 GHz, 20 GHz
- ▶ Connectivity
 - Long reach solder tip
 - Probing Module for handheld or fixtured probing
- ▶ Usability
 - TriMode™ capability
 - Quick connect RF connectors
 - Convenient indicators and control of probe settings from the probe



TriMode Probing

TriMode, with a single probe-DUT connection, allows:

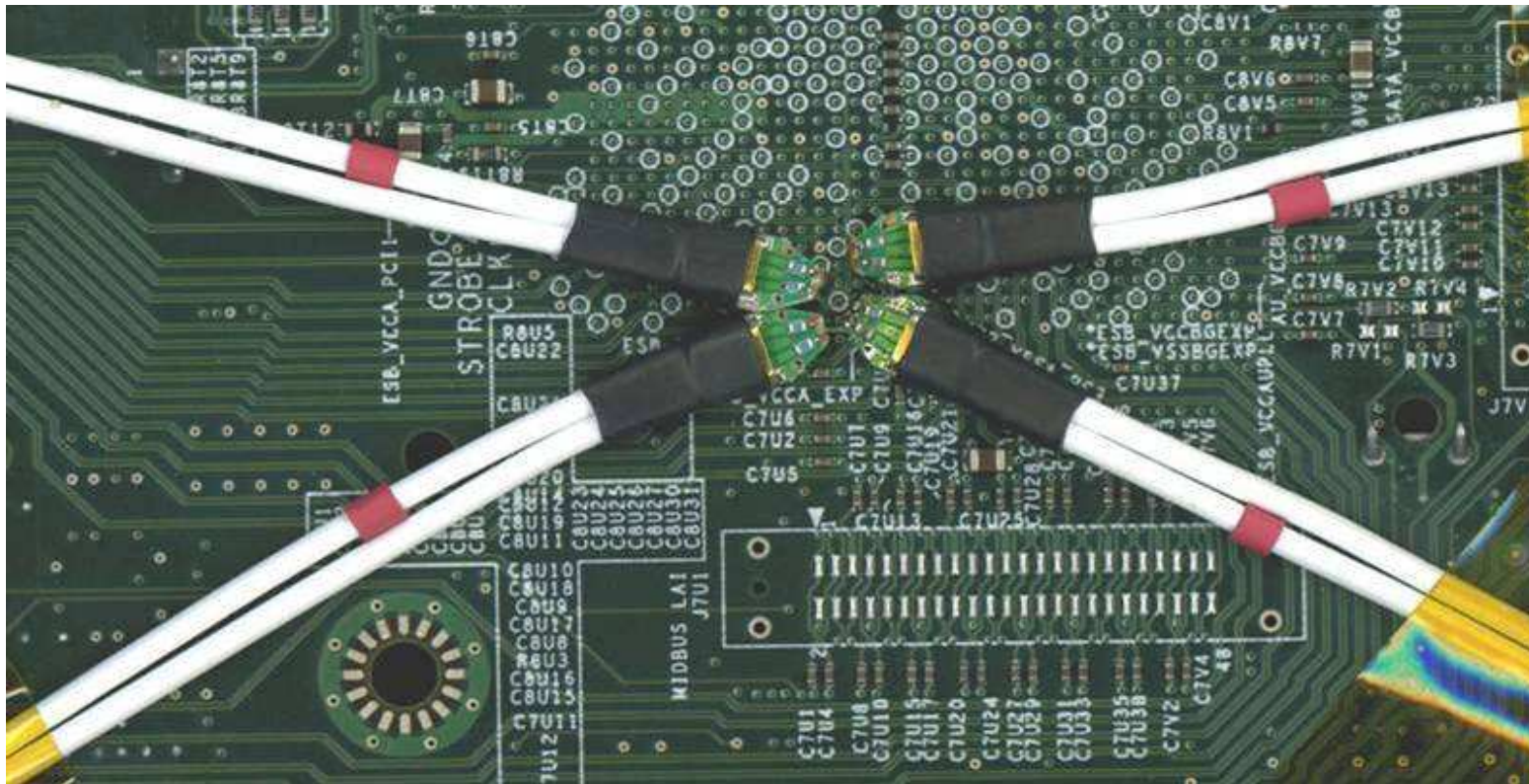
- Traditional differential measurements: V+ to V-
 - Independent single ended measurements on either input
 - ▶ V+ with respect to ground
 - ▶ V- with respect to ground
 - Direct common mode measurements: $(V+) + (V-)/2$ with respect to ground
- ▶ Serial Data standards such as PCI Express, Serial ATA, etc require both differential and maximum permissible common mode voltage limit measurements. Requires two separate probes --- **Until Now!**



P75TLRST

TriMode Long Reach Solder Tip

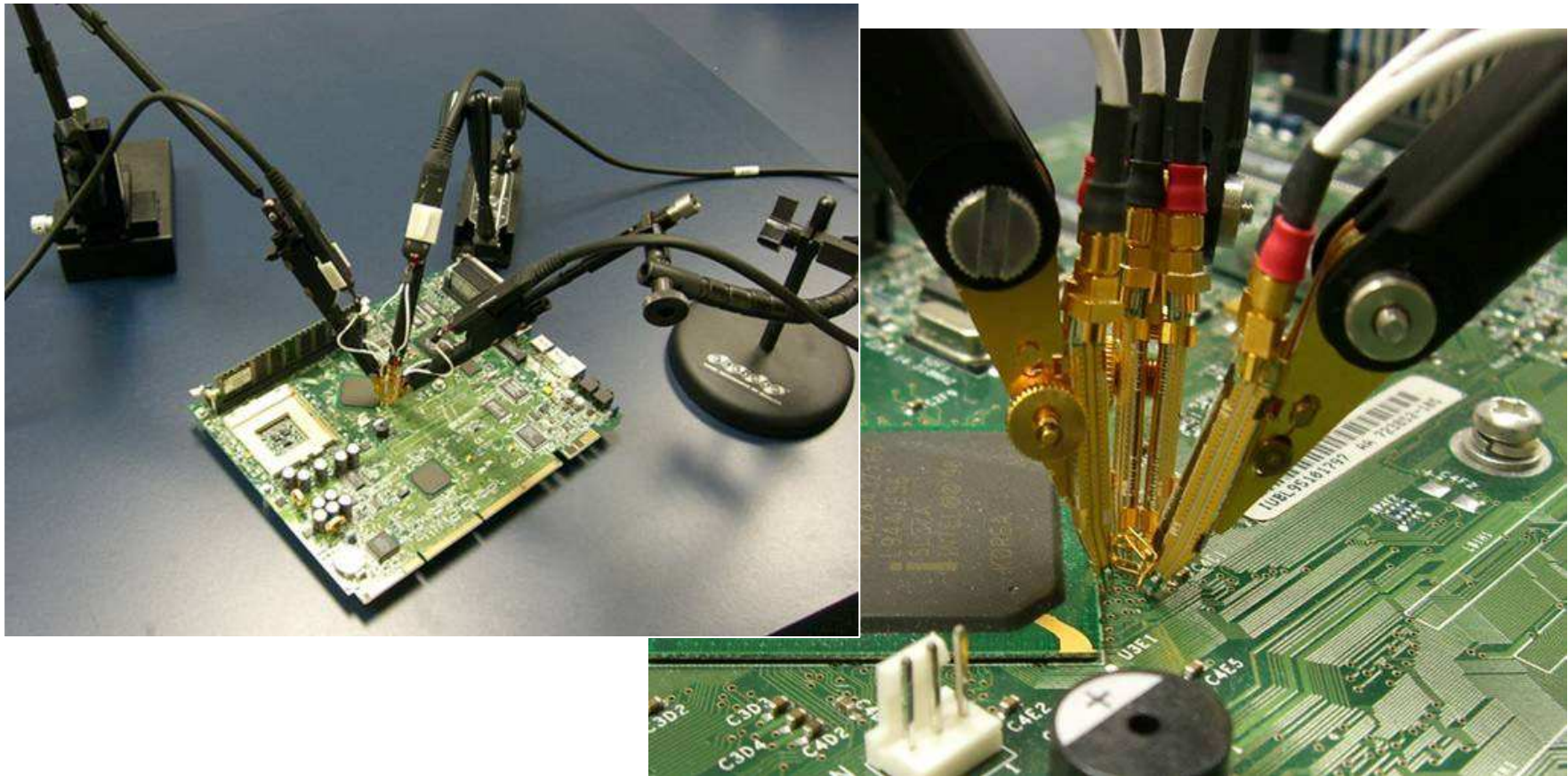
- ▶ Solder-in tip has very small geometry tip, allowing multiple tips to be inserted into DUT in small space
- ▶ Long reach cable to access small, confined areas



P75PDPM

Precision Differential Probing Module

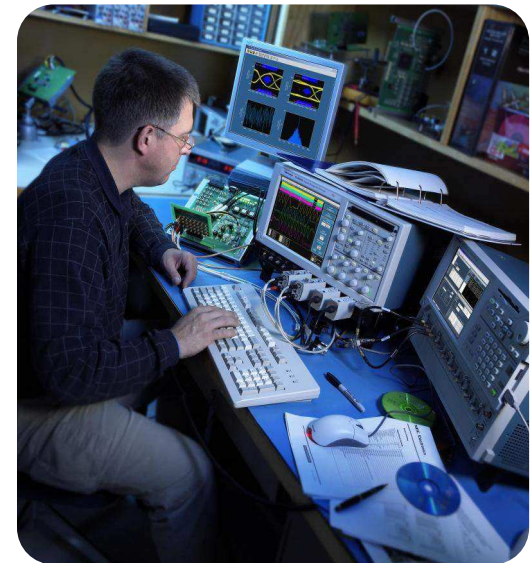
- ▶ Access multiple test points in small space
- ▶ Probing module can be hand-held or fixtured



DUT Connection

SMA Probes

- ▶ Oscilloscope inputs are single-ended, although many serial data standards are differential
- ▶ Differential SMA Probes
 - Convenient differential amplifier
 - Acquire 4 differential signals simultaneously on a single oscilloscope
 - Easier oscilloscope setup (single channel vs. two channel pseudo-differential)
 - Inputs are skew matched
 - Compensated for cable loss
- ▶ Ideal for compliance testing
 - Simple input structure has better input return loss than oscilloscopes
 - Termination voltage control for standards with non-zero DC common mode voltages



DUT Connection

P7313SMA – High Performance SMA Probes

- ▶ >13 GHz Bandwidth
- ▶ Dual SMA inputs to internal 50 ohm precision termination network
- ▶ Termination Voltage Control
 - Perfect for standards requiring a non-zero termination voltage like **HDMI**
 - V_{TERM} range: +3.6V / -2.5V
- ▶ Calibrated to the end of the cables
 - <1ps skew between matched cables



Triggering in 3D (volts, time, channels)

- ▶ Complex signals call for Advanced Triggers
- ▶ The trigger system “separates the wheat from the chaff”
- ▶ Triggering can be single shot or repetitive
 - And can initiate further processing and measurements
- ▶ Simplest case is an edge trigger
 - But there are *thousands* of advanced trigger combinations
 - Advanced Trigger User Interface is critical

HW Triggering: A then B

The screenshot displays a Tektronix oscilloscope interface. At the top, a menu bar includes File, Edit, Vertical, Horiz/Acq, Trig, Display, Cursors, Measure, Mask, Math, MyScope, Analyze, Utilities, and Help. The main display shows a high-frequency signal with a central burst highlighted in yellow. Below the display, the text reads "6 Gb/s CJTPAT" and "Trigger: data high > 880 ps, then data low > 800 ps".

Below the display, there are several control panels:

- Channel 1 (C1) settings: 90.0mV/div, 50Ω, BW:10.0G, D_S.
- Trigger settings: A (C1) Time 0.0V, Trig Dly: 3.2ns; B (C1) Time -3.6mV.
- Acquisition settings: 40.0ns, 50.0GS/s, 20.0ps/pt, Run, Sample, 88 793 acqs, RL:20.0k, Auto, April 15, 2008, 15:08:29.

The bottom panel is titled "Trigger - A->B Sequence" and shows a flowchart for the trigger sequence: A only → A then B → Trig After Time → Trig on nth Event. The "A then B" sequence is selected. The "Horizontal Delay Mode" is set to "Off". A diagram shows the trigger delay of 3.2ns. The "Horizontal Position" is 58.54%. The "Trigger Reset" section shows the "Type" set to "None" and a note: "Wait indefinitely for B Event After A trigger".

Triggering in 3D (volts, time, channels)

- ▶ Search & Mark
 - A.K.A. Software Triggers
- ▶ Post acquisition waveform processing
 - 1 or 2 levels of HW trigger can still be used
 - Then Search & Mark does it's magic
 - Pick up where HW Triggers run out of performance
 - ▶ Limited only by digitizer performance
 - Can "Stop" the acquisition, i.e. "trigger"
 - ▶ "3rd Level" of triggering
- ▶ Search & Mark can find up to 8 kinds of events
 - "Trigger" on up to 8 events in parallel, on any channels
- ▶ Search & Mark finds all events across entire acquisition
 - "Trigger" multiple times per sweep

Search & Mark: "Trigger"

6 Gb/s CJTPAT

Search & Mark: (data high or low > 800 ps) OR (+/- Runt)

C1 90.0mV/div 50Ω E_W:10.0G D_S
 Z1C1 90.0mV 200ps -64.5ns -62.5ns

20.0ns 50.0GS/s IT 4.0ps/pt
 Stopped
 7 acqs RL:50.0k
 Auto April 15, 2008 14:25:22

Search - Select

Select
 Configure
 Results
 View
 Mode

Edge Glitch Width Setup/Hold
 Runt Window Pattern
 Transition Timeout State

	Type	Source
1	Timeout	Ch1
2	Runt	Ch1

Clear Selected Clear All

Search On
 Mark
 Prev Next
 Set/Clr
 Bring Cursor to Mark
 Cursor 1 Cursor 2
 Bring Zoom to Mark
 Zoom 2 Zoom 3

There's a secretary in my scope

- ▶ After a "heavy" topic like triggering, we need a breather :~)
- ▶ Scopes make complex measurements, and you need to document your work. The job's not complete 'til the paper work is done!
- ▶ Let's take a look at some features to help you create your reports (or PowerPoint slides like these :~)
 - On-screen notes and screenshots
 - Waveform data and measurements export
 - Word and Excel Toolbars
 - Report generators

Export Waveform to CSV file

The screenshot shows the Tektronix oscilloscope software interface. The main window displays a waveform with the following settings:

- 6 Gb/s CJTPAT
- Trigger: data high > 880 ps, then data low > 800 ps
- Scale: 90.0mV/div, 50Ω, R_w:10.0G, D_S
- Time: 40.0ns, 50.0GS/s, 20.0ps/pt
- Trig Dly: 3.2ns
- Run Sample
- 127 323 acqs, RL:20.0k
- Auto April 15, 2008 15:24:19

Two dialog boxes are open:

- Save As:** Shows the source as 'Ch1', save location as 'My Documents', and file name as '080415_152354'. The save type is 'Tektronix Waveform Data (*.wfm)'. There are checkboxes for 'Auto-increment file name', 'Prompt for file name before saving', and 'Set Front Panel Print Button to Save'.
- Waveform Save Options:** Shows 'Waveform Data Range' set to 'Samples 1 to 1', 'Data Destination' set to 'Matlab', and 'Number of Samples: 20000'. It also has sections for 'FastFrame Data Range' (set to 'All Frames') and 'Waveform Detail' (checked 'Include waveform scale factors').

Excel Toolbar

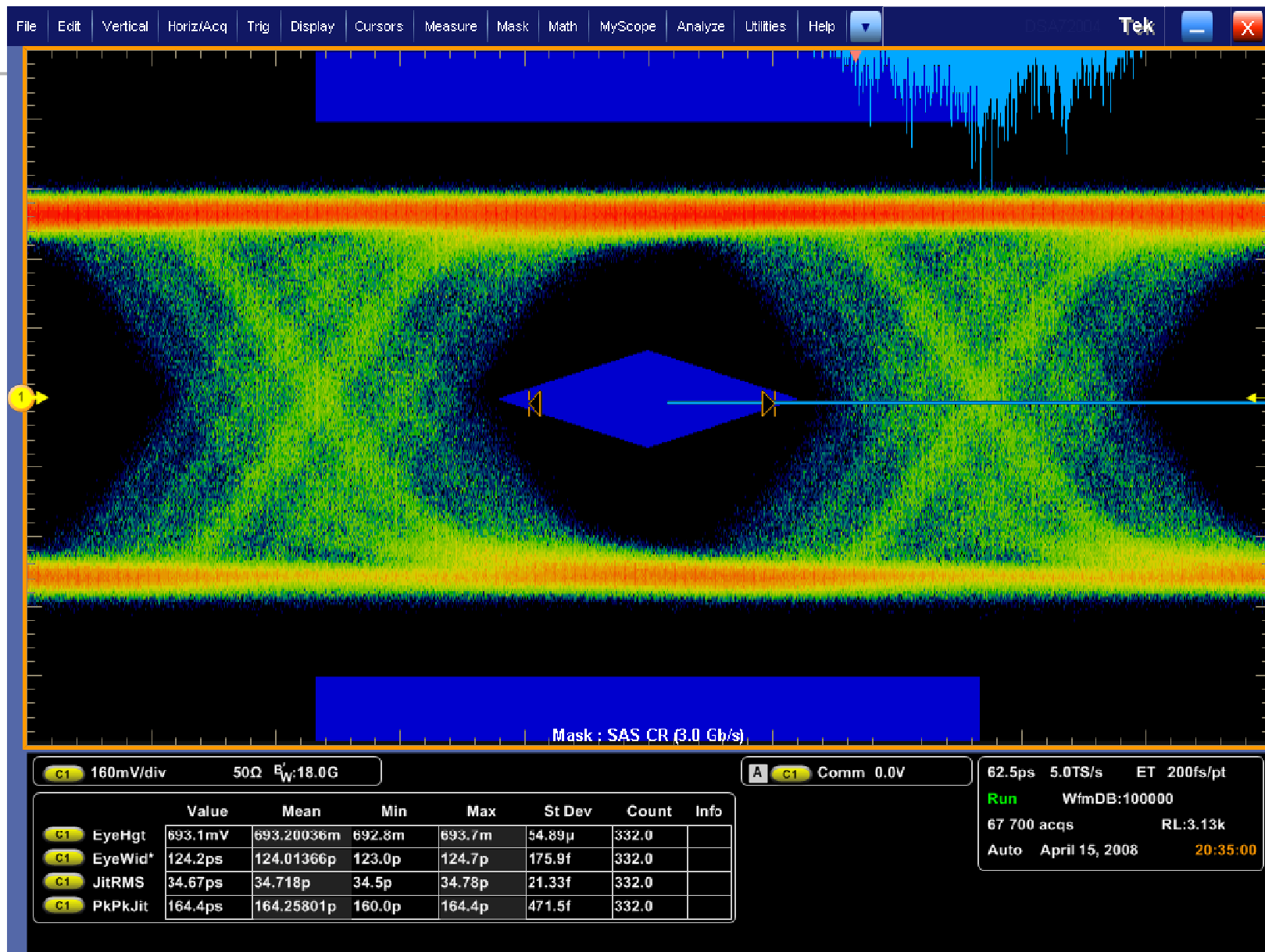
The screenshot shows a Microsoft Excel window titled "Microsoft Excel - Book1". The menu bar includes File, Edit, View, Insert, Format, Tools, Data, Window, and Help. The toolbar contains various icons for file operations, editing, and formatting. The active cell is A1, containing the formula = s. The spreadsheet displays a table with two columns: time (s) and voltage (V). A waveform graph is overlaid on the data, showing a square wave signal. The graph is titled "CH1 (V)" and has a legend below it. A "TekXL Waveform Capture - GPIB8::1::INSTR" dialog box is open, showing settings for the capture. The dialog box includes a list of active channels (CH1), a Refresh button, a Record Length field set to 1000, Start Display In settings (Column A, Row 1, A1), checkboxes for Generate Excel Graph, AutoFormat (Width), and Place Graph In (Active Sheet, New Sheet). A "TekXL Toolbar" is also visible, containing icons for capture, zoom, and help. The status bar at the bottom shows "Ready" and "NUM".

Time (s)	Voltage (V)
1.00	-3024
2.00	-3024
3.00	-3024
4.00	-3024
5.00	-306
6.00	-306
7.00	-3096
8.00	-3132
9.00	-3132
10.00	-3168
11.00	-3168
12.00	-3204
13.00	-324
14.00	-324
15.00	-324
16.00	-324
17.00	-324
18.00	-324
19.00	-3204
20.00	-3168
21.00	-3132
22.00	-3096
23.00	-306
24.00	-3024
25.00	-2988
26.00	-2916
27.00	-288
28.00	-2844
29.00	-2808
30.00	-2772
31.00	-2736
32.00	-2736
33.00	-2736
34.00	-2736

One bad bit spoils the whole bunch

- ▶ Historically, repetitive eye diagrams and mask testing were the norm for telecomm and datacomm signals
 - Years ago this was a purchased option, then became standard feature
 - Requires clock for triggering, or hardware CR trigger
 - Relies on statistics, probability to predict link performance
 - No ability to decompose Random versus Deterministic jitter and noise
 - ▶ Exception: DSA8200 series with 80A06 and 80SJNB...
 - Still useful for quick analysis: “Like total cholesterol”
- ▶ Over the last decade, real time single shot measurements have emerged as the preferred/required method
 - Up until recently a purchased option, now standard on DSA70000 series
 - Measures every bit, shows jitter frequency, Rj/Dj and much more
 - Can be complex. Prior SW was hard to understand and use.
 - DPOJET: Jitter and Eye Test
 - ▶ Fast, Easy, Productive

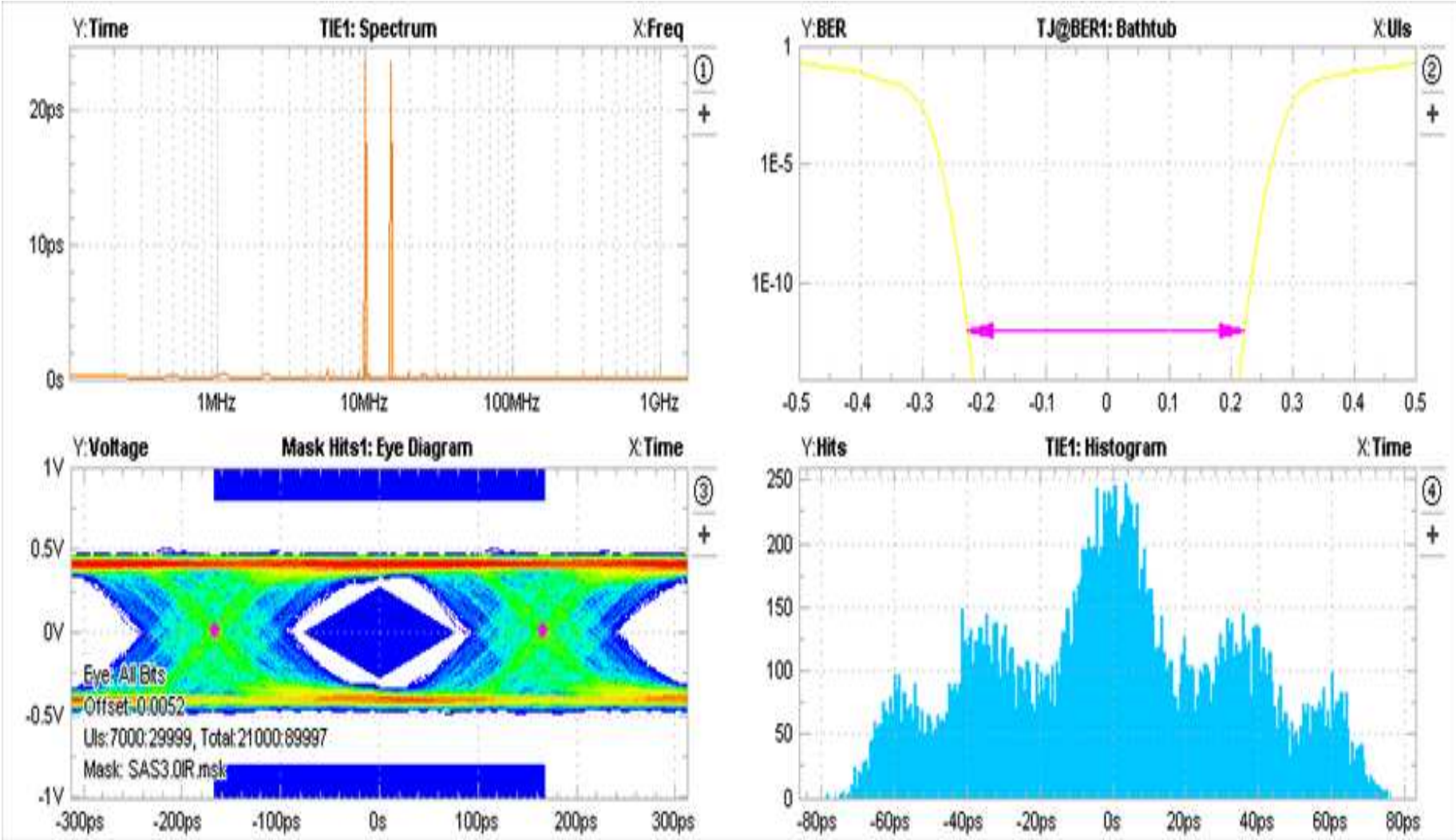
ET Eye – Equivalent Time Sampling



DPOJET

- ▶ DPOJET provides in depth jitter and eye diagram analysis
- ▶ EASY to use, EASY to document
- ▶ Accurately predicts Eye Opening @ BER based on Rj / Dj
- ▶ Pinpoints Dj frequencies
- ▶ Highlights bit errors
- ▶ Click the link to view report
 - [DPOJET Report.mht](#)

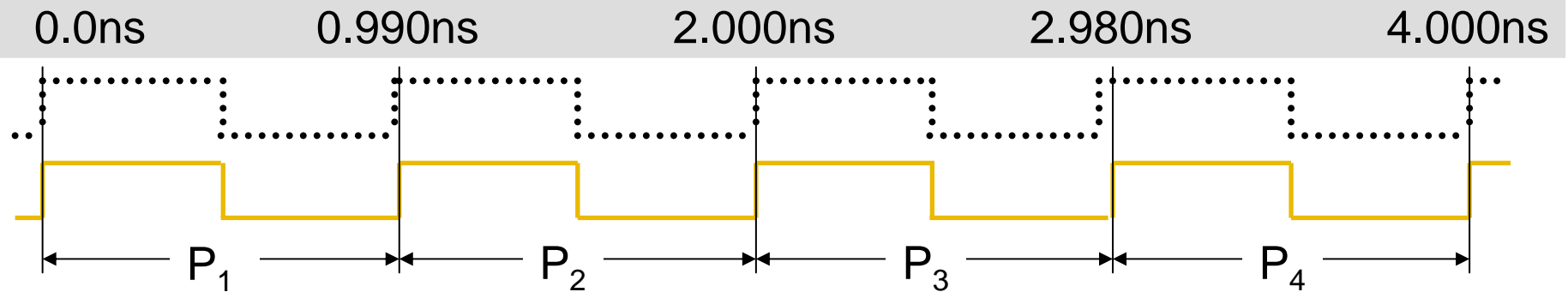
DPOJET Summary Plot



Punctuality is a virtue - TIE

- ▶ When it comes to serial digital data, being early is just as bad as being late. Clock Recovery tracks low frequency jitter, passes high frequency jitter. Most CR problems are in the mid frequency range, near the loop BW, typically data rate/1667.
- ▶ TIE, time interval error, measures the data signal with respect to a reference clock.
- ▶ Repetitive/ET Eye solutions use a clock signal to trigger the scope, and therefore display TIE directly
 - Can be a challenge to provide the clock signal
- ▶ DPOJET supports six different reference clock techniques.
 - Derived from data: Mean, Median, Standard PLL, Custom PLL
 - Explicit Clock: Edge, PLL
 - Specified Data Rate

► Jitter Measurements: Period, Cycle to Cycle, TIE



P	0.990ns	1.010ns	0.980ns	1.020ns
Cy-Cy	0.020ns	-0.030ns	0.040ns	
TIE	-0.010ns	0.000ns	-0.020ns	0.000ns

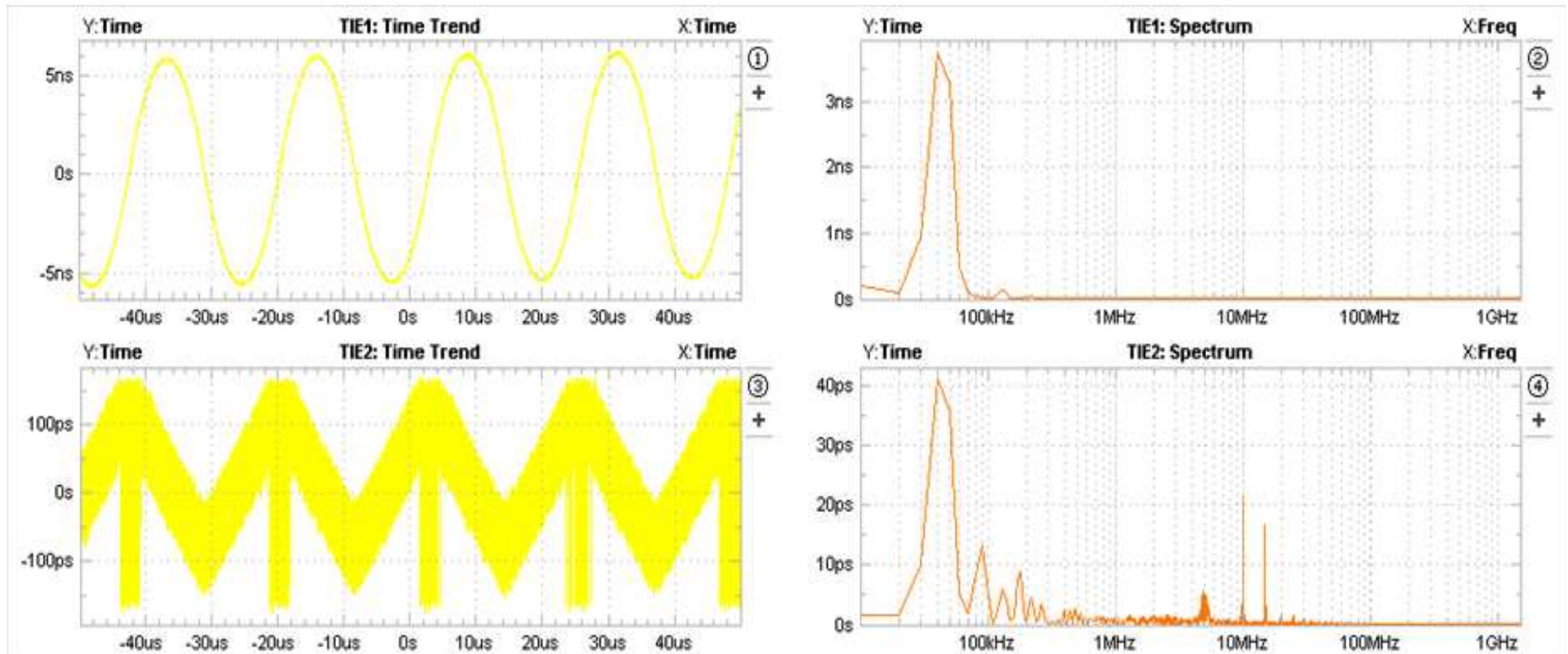
Period Jitter = 18.3ps StdDv (0.990/1.010/0.980/1.020) 40ps p-p

Cy-Cy Jitter = 36.1ps StdDv (0.020/-0.030/0.040) 70ps p-p

TIE = 9.6ps StdDv (-0.010/0.000/-0.020/0.000) 20ps p-p

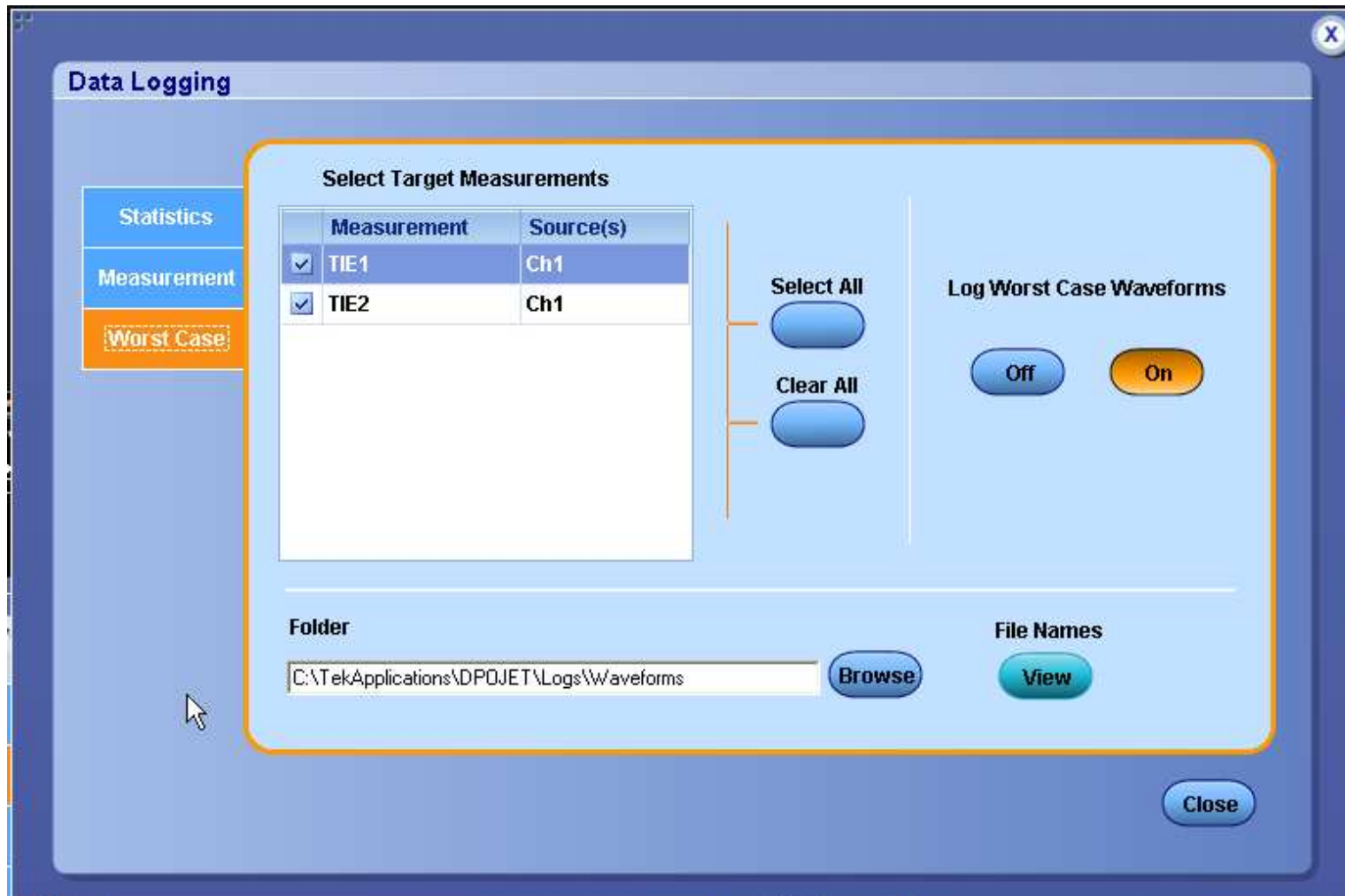
DPOJET – TIE measurement on SSC

- ▶ TIE1: Ref Clock = Mean, shows SSC
- ▶ TIE2: Ref Clock = PLL, tracks out SSC
- ▶ Report: [DPOJET Report TIE SSC.mht](#)



DPOJET – “Trigger” on TIE

- ▶ Automatically save worst case waveforms...



But will it work?

- ▶ Compliance testing is important, even if you don't need the logo.
- ▶ The goal of compliance testing is interoperability
 - Across vendor's products
 - Within your own products
- ▶ Tektronix offers a large suite of compliance test solutions
 - Ethernet
 - USB
 - PCIe
 - InfiniiBand
 - SATA, SAS
 - HDMI, DVI, Display Port
 - Etc., etc.

In Closing...

- ▶ Any Questions?

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- ▶ Mike Tranchemontagne, Tektronix FAE
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- ▶ Demo Instruments: DSA72004, AWG7102

- ▶ Thank You!