終極王牌特訓班-高速串列測試之最後進擊

Jitter(抖動)及Eye Diagram(眼狀圖)的量測分析原理與應用

Jacky Huang
太克科技量測儀器技術部門，技術經理

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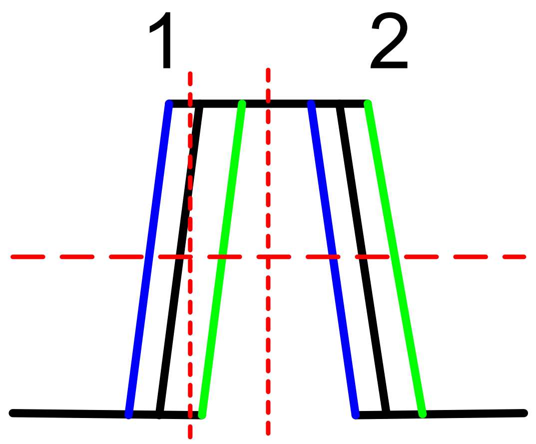
Agenda

- Background Information
- Jitter Basics
  – What is Jitter?
  – TIE vs. Period Jitter vs. Cycle-to-Cycle
  – Clock Recovery
  – Jitter Visualization
- Advanced Analysis – Jitter Decomposition
  – Motivation
  – Terminology and Models
  – Dual-Dirac
- Tektronix DPOJET Overview
- Q & A



Jitter-Related Tools on Tektronix RT Scopes

- TDSJIT3, TDSJIT3v2
  - Introduced ~2002
  - First Real-Time Scope tool to do Rj/Dj analysis
  - Focused on general-purpose analysis and debug

- RT-Eye
  - Focused on compliance for serial standards
  - Addition of eye diagrams and other vertical measurements
  - Large portions of algorithm code ported from TDSJIT3 and extensively checked for correlation

- DPOJET
  - Merges eye diagrams and other vertical measurements from RT-Eye with the extensive general toolbox of TDSJIT3
  - Integrated with the scope (UI, memory management, etc)
  - Platform for future enhancements and development

Managing Complexity

Easy to Drive

Lots of Capabilities

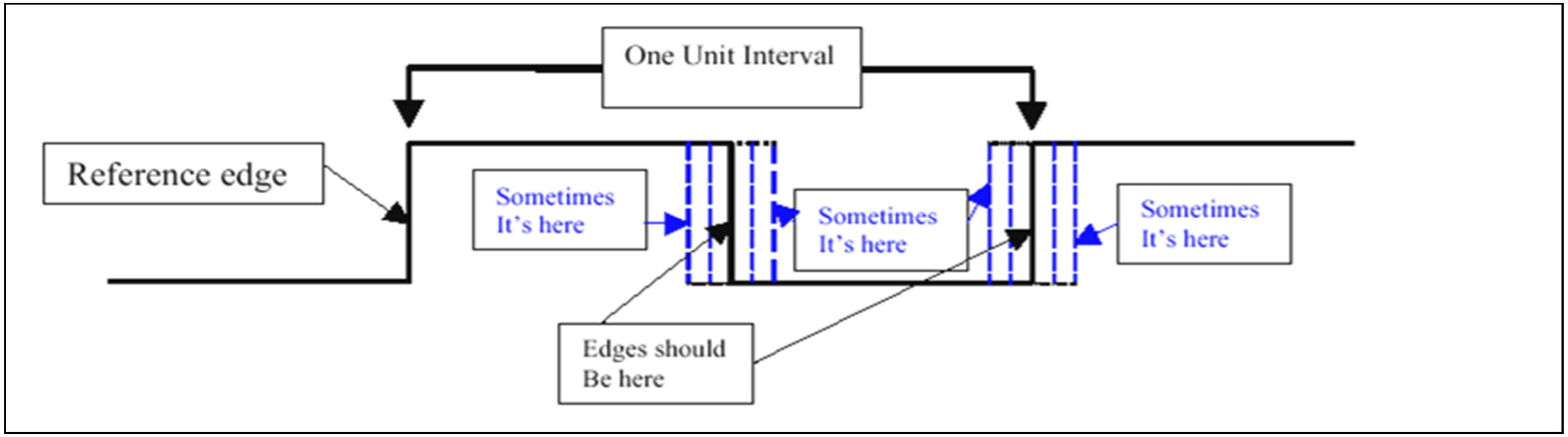
How can we have both?

Jitter Basics

Definitions / Clock-Recovery / Visualization Tools

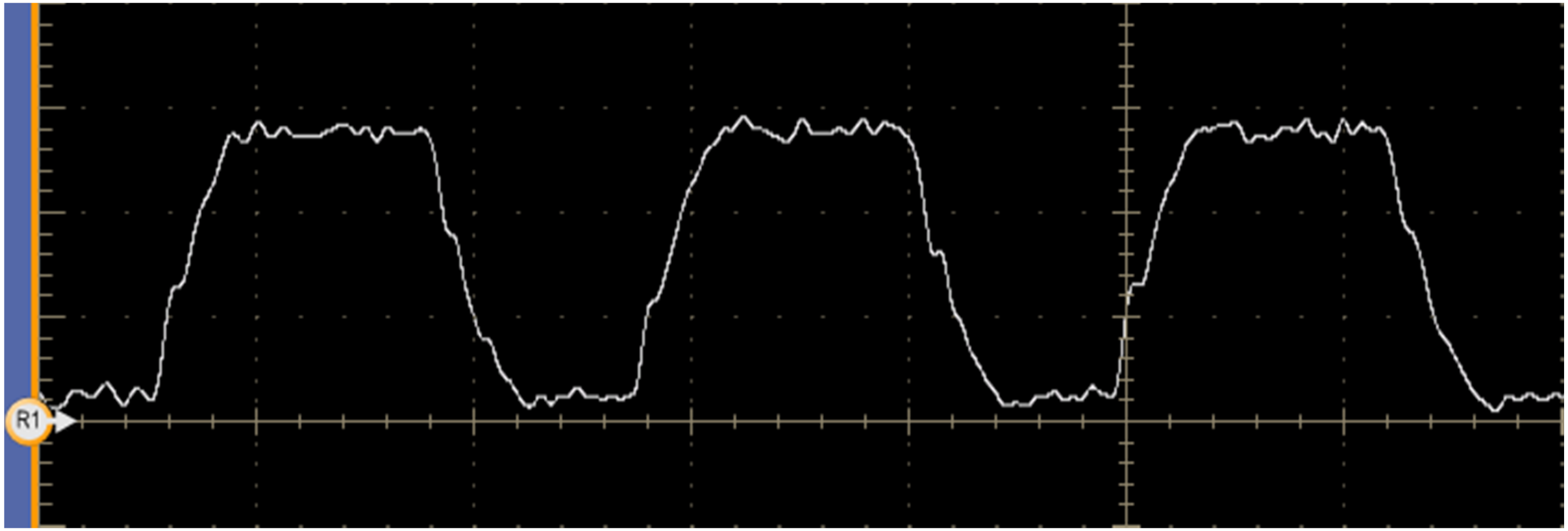
What is Jitter?

- Definitions
  - "The deviation of an edge from where it should be"
  - ITU Definition of Jitter: "Short-term variations of the significant instants of a digital signal from their ideal positions in time"



Facing Reality

- In real life, signals don't have vertical edges and flat tops / bottoms…



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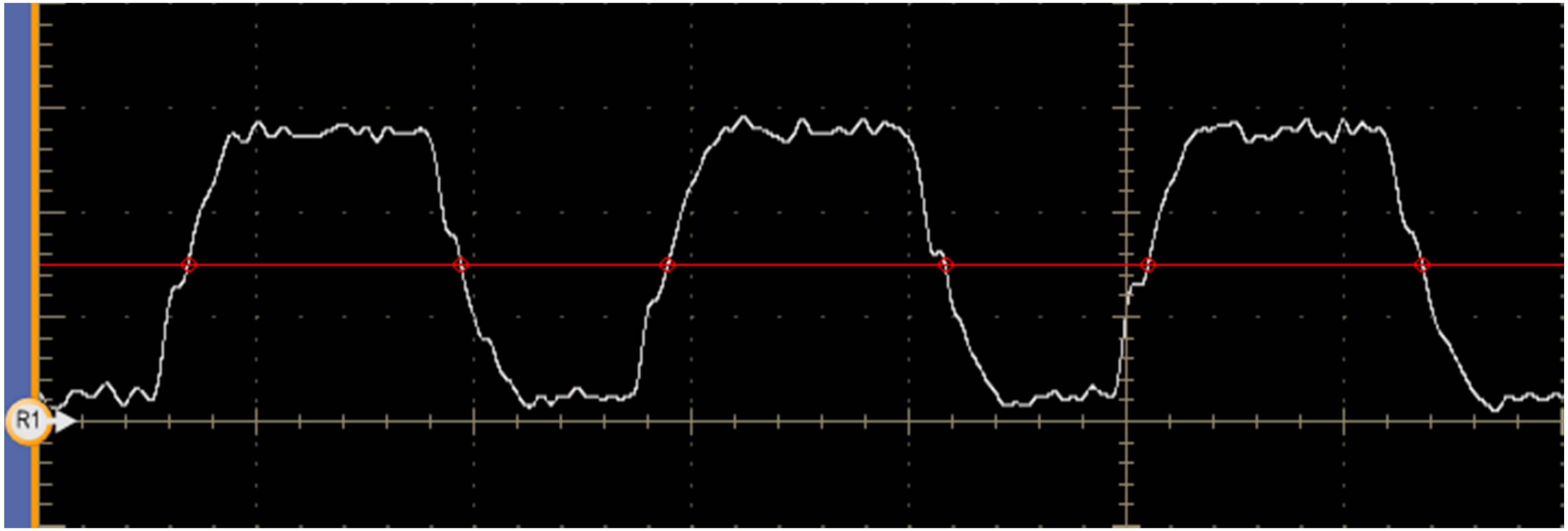

  - One or more **Reference Levels** must be specified before edges can be defined
    - Jitter Correlation is especially sensitive to reference levels

Facing Reality

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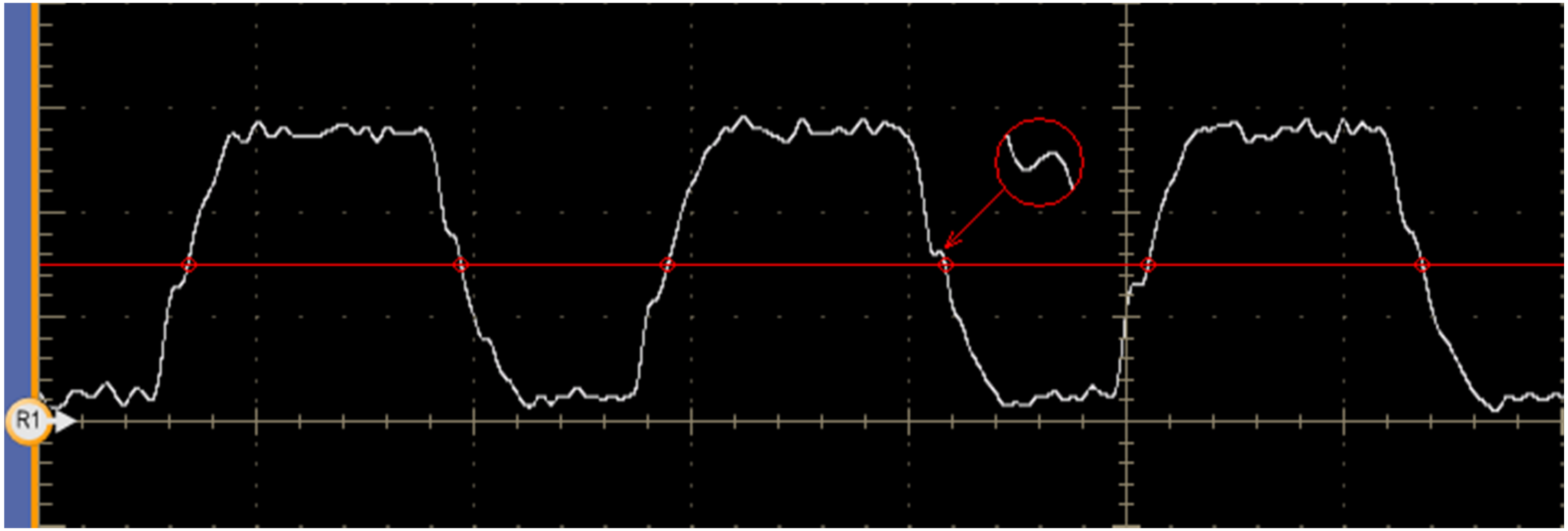

- One or more **Reference Levels** must be specified before edges can be defined
  - Jitter Correlation is especially sensitive to reference levels

- **Hysteresis** may be needed to prevent false edge recognition

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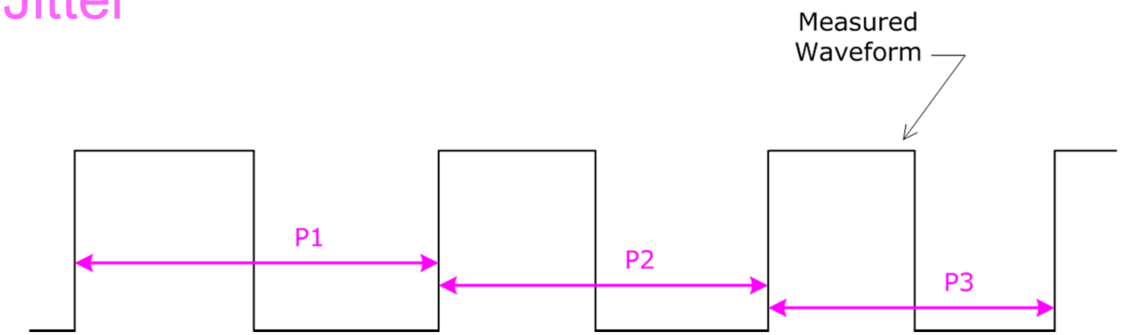
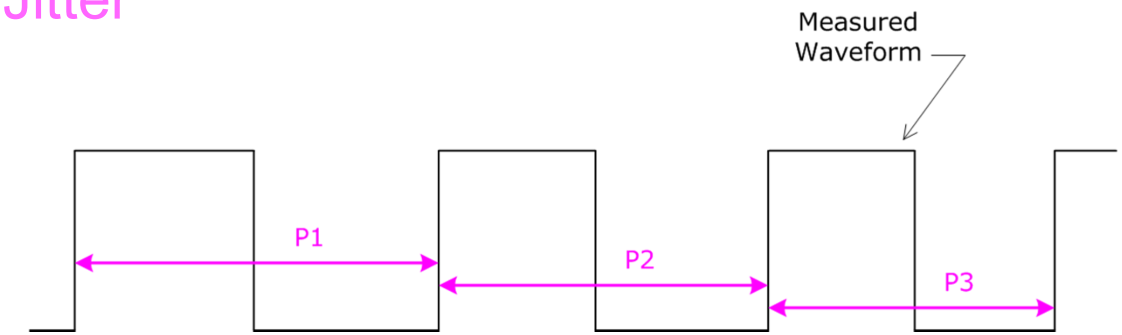
Types of Jitter

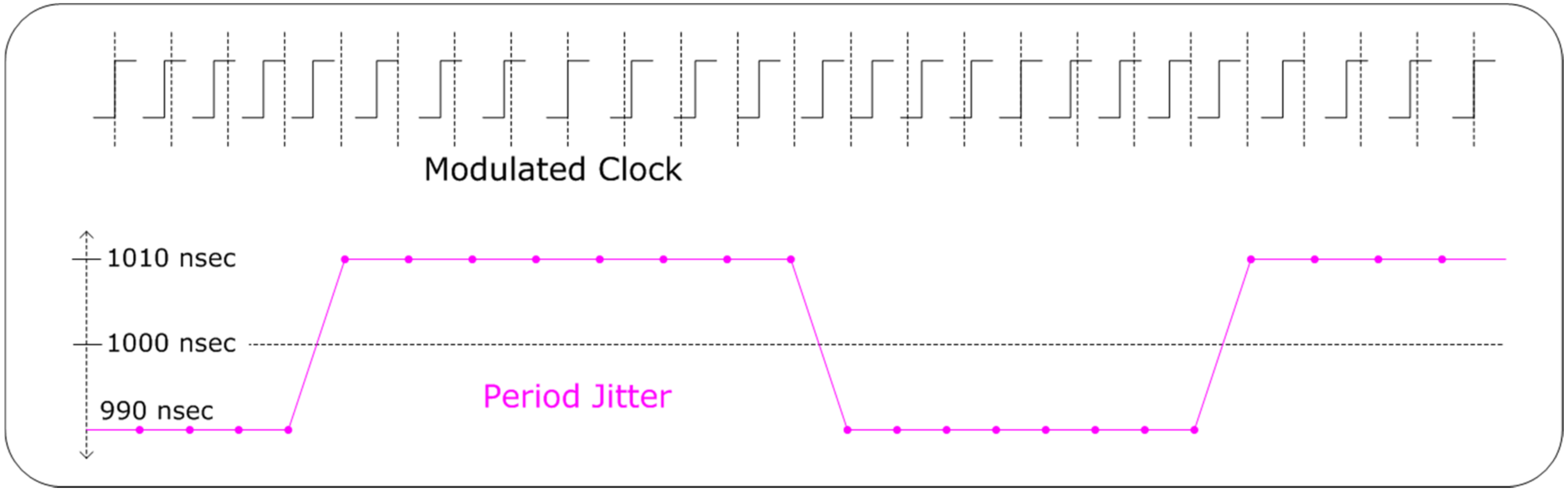
- Period Jitter



Types of Jitter

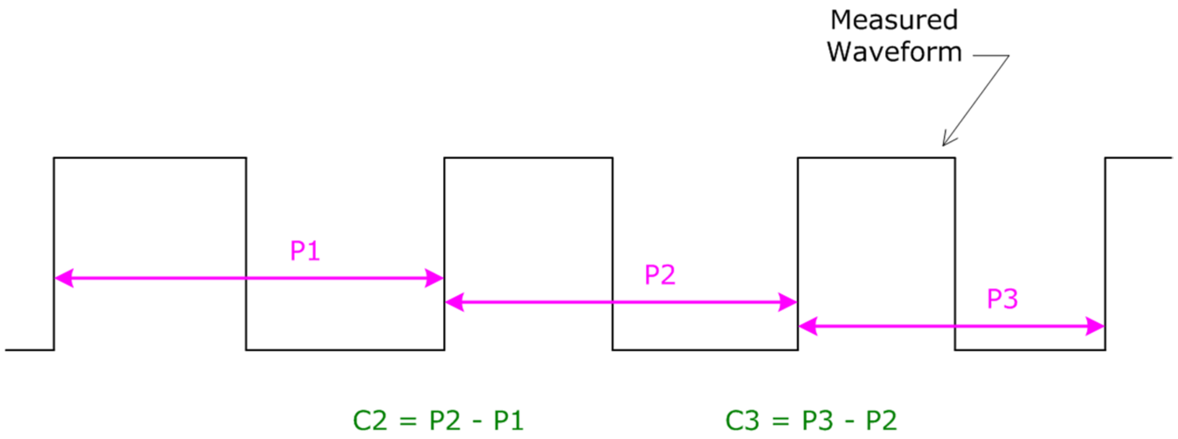
- Period Jitter





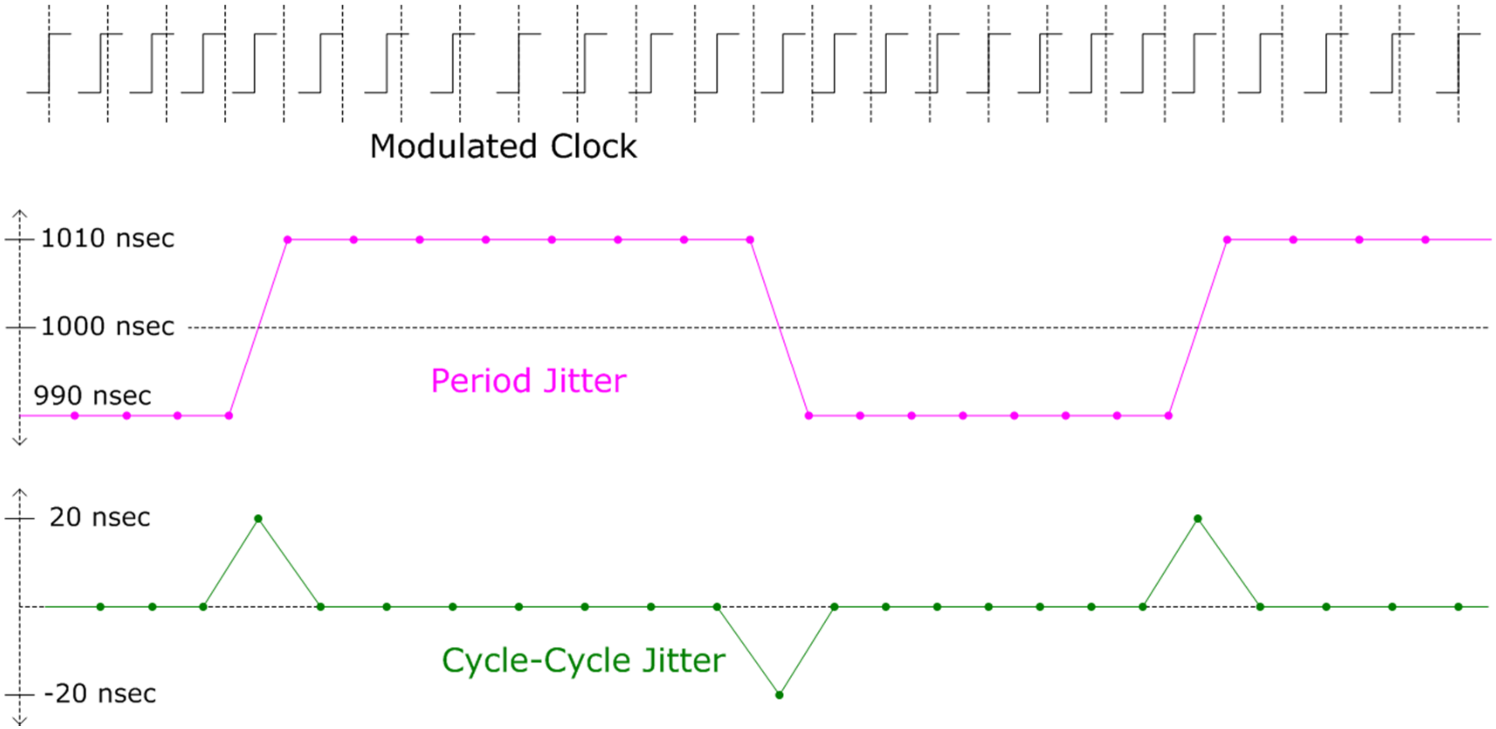
Types of Jitter

- Period Jitter
  Cycle-to-Cycle Jitter



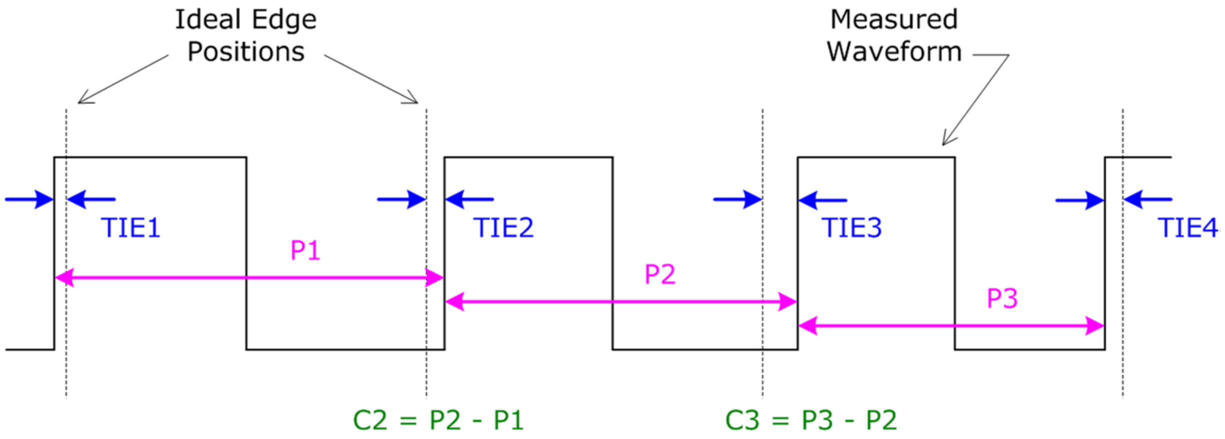
– **Cycle-to-Cycle Jitter** is the first-order difference of the Period Jitter

Types of Jitter (Visualization)



Types of Jitter

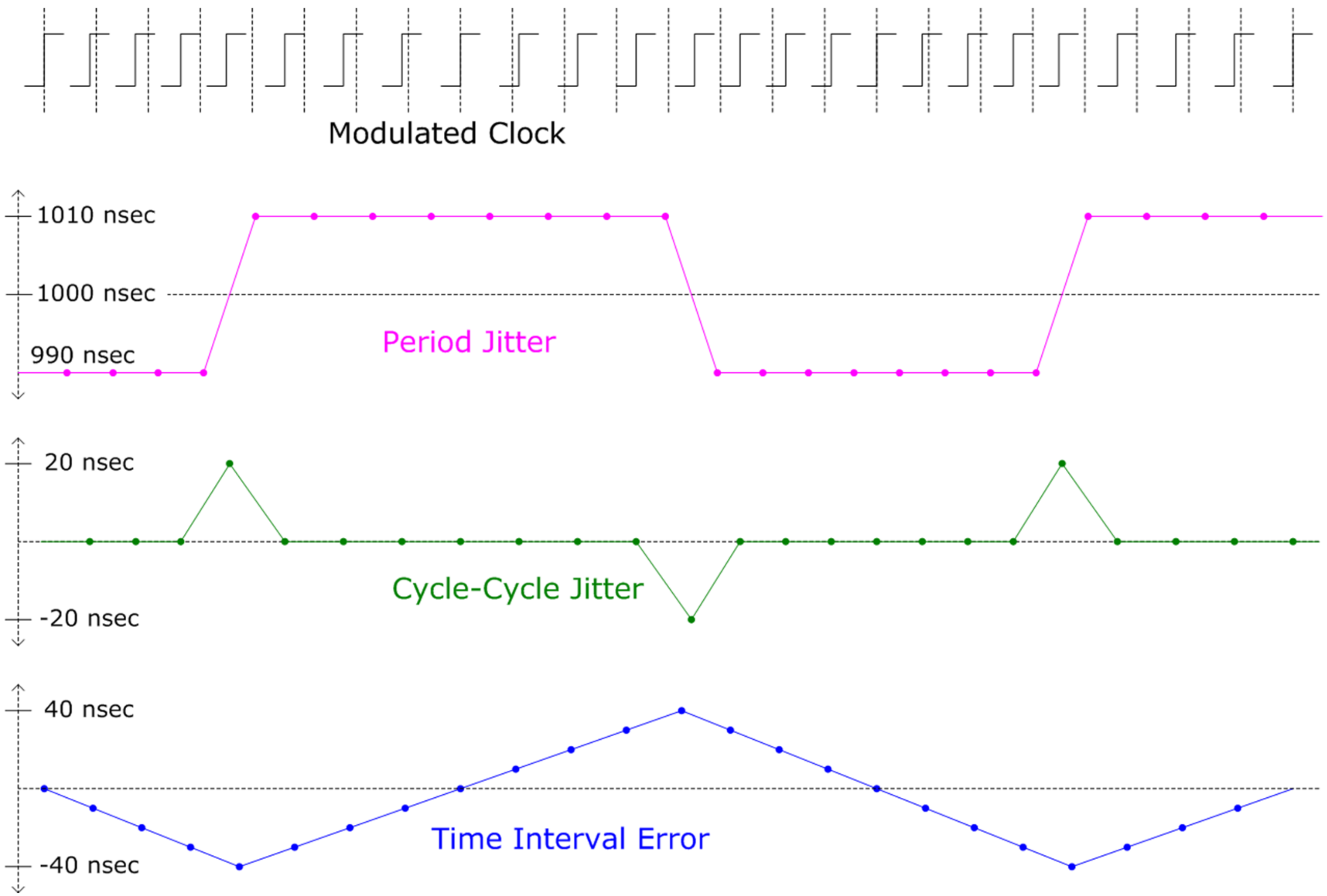
- Period Jitter
  Cycle-to-Cycle Jitter
  TIE (Time Interval Error)



– **Period Jitter** is the first-order difference of the **TIE Jitter** (plus a constant)

$$P_n = TIE_n - TIE_{n-1} + K$$

Types of Jitter (Visualization)

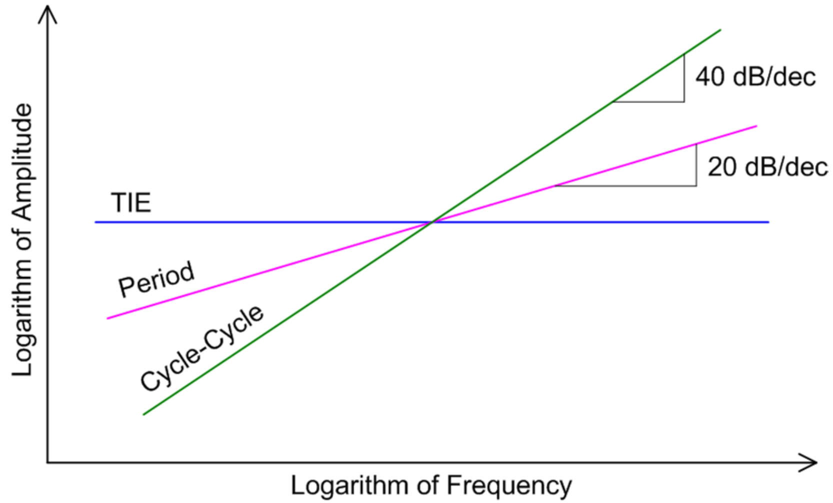


Mathematical Connection between Jitter Types

$$y(t) = \frac{\partial x(t)}{\partial t}$$

$\Updownarrow$ Laplace Transform

$$Y(s) = s \cdot X(s)$$

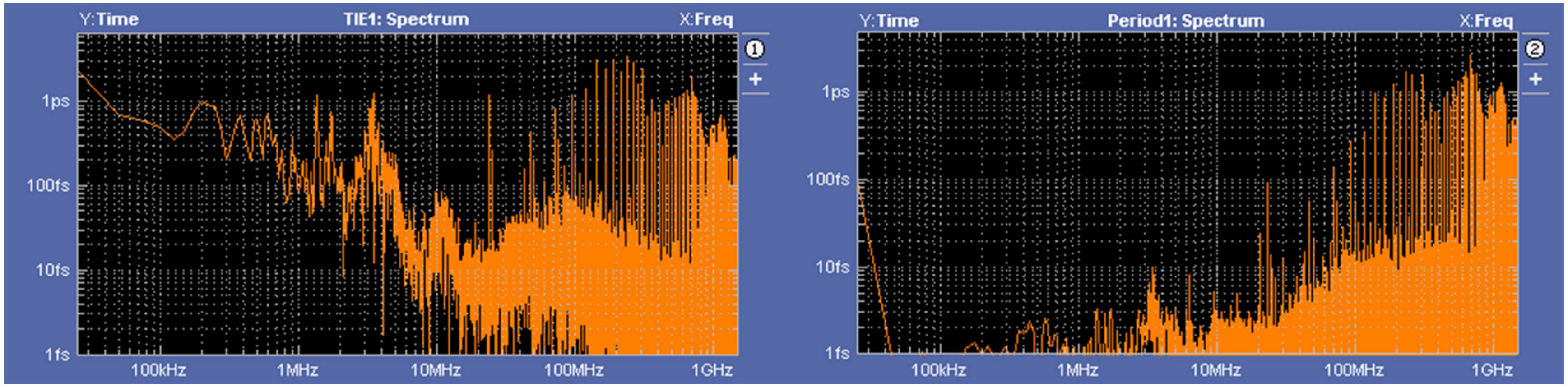


TIE Jitter $\leftrightarrow$ Phase Modulation $\leftrightarrow$ $\phi(t)$

Period Jitter $\leftrightarrow$ Frequency Modulation $\leftrightarrow$ $\Phi(t)$

TIE vs. Period Jitter: Actual Example

- This figure shows the measured TIE and Period Jitter vs. Frequency for a SATA drive. The many spikes in the jitter spectrums are data-dependent jitter related to the 127-bit PRBS pattern



TIE Jitter needs a Reference Clock

- The process of identifying the reference clock is called Clock Recovery.
- There are several ways to define the reference clock:
  - Constant Clock with Minimum Mean Squared Error
    - This is the mathematically “ideal” clock
    - But, only applicable when post-processing a finite-length waveform
    - Best for showing very-low-frequency effects
    - Also shows very-low-frequency effects of scope’s timebase
  - Phase Locked Loop (e.g. Golden PLL)
    - Tracks low-frequency jitter (e.g. clock drift)
    - Models “real world” clock recovery circuits very well
  - Explicit Clock
    - The clock is not recovered, but is directly probed
  - Explicit Clock (Subrate)
    - The clock is directly probed, but must be multiplied up by some integral factor

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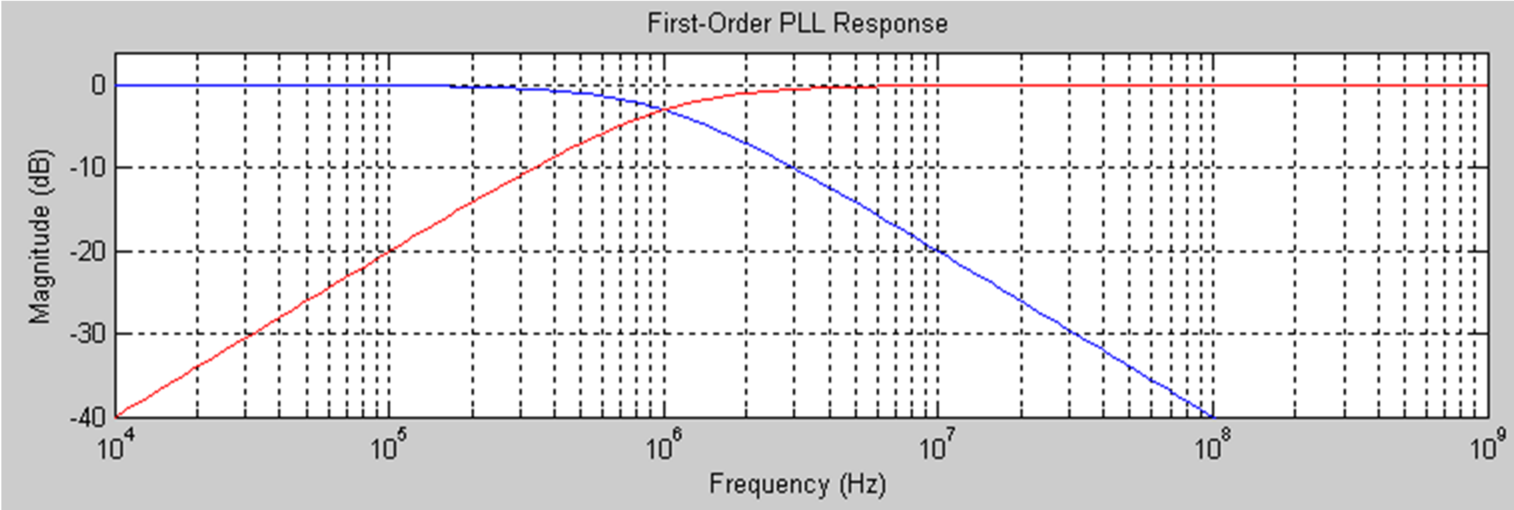
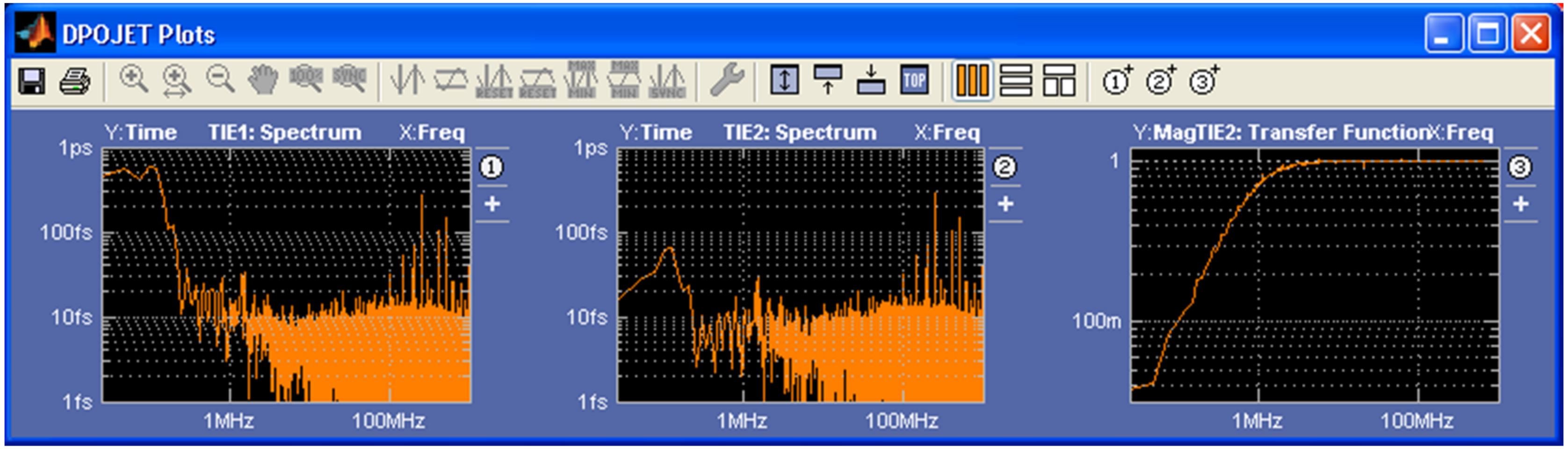
PLL Clock Recovery: Phase and Error Response





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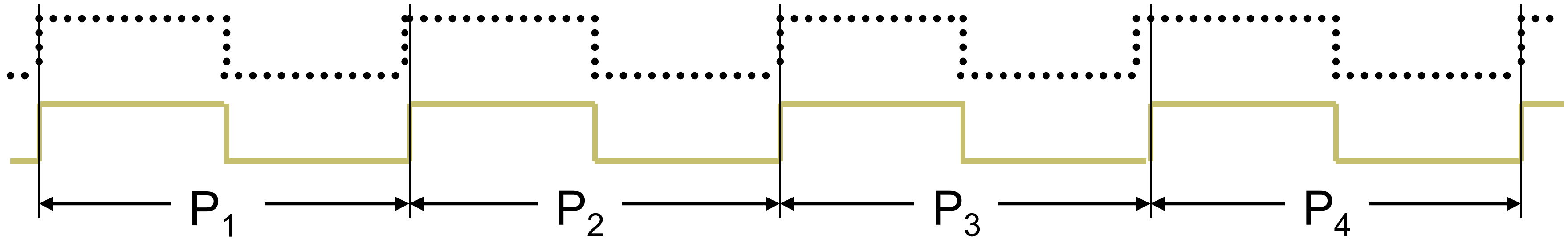
Same Signal, Different Results

0.0ns 0.990ns 2.000ns 2.980ns 4.000ns



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 StdDev	(0.990/1.010/0.980/1.020)	40ps p-p
Cy-Cy Jitter	= 36.1ps StdDev	(0.020/-0.030/0.040)	70ps p-p
TIE	= 8.9ps StdDev	(0.00/-0.01/0.00/-0.02/0.00)	20ps p-p

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Key Points

- In order to define edges within real signals, we must first identify one or more **reference levels**.
  - Reference levels have a great deal of influence over jitter measurements.
  - Improper choice of reference levels can cause clock recovery problems

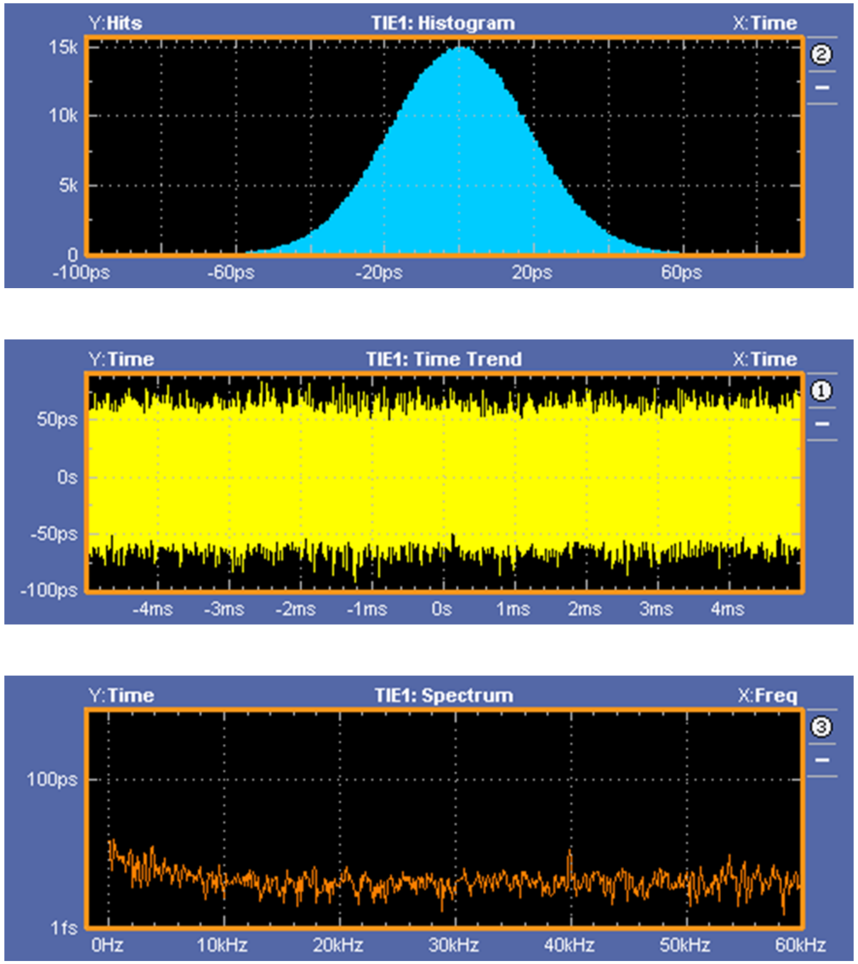
- Different type of jitter measurement (TIE, Period, Cy-Cy) are mathematically related but
  - Emphasize (or hide) different parts of the frequency spectrum
  - Can distort modulation shapes due to integration or differentiation

- For TIE measurements, **clock recovery** is used to establish “ideal” clock locations. Choice of clock recovery method and its parameters can greatly influence how jitter is revealed.

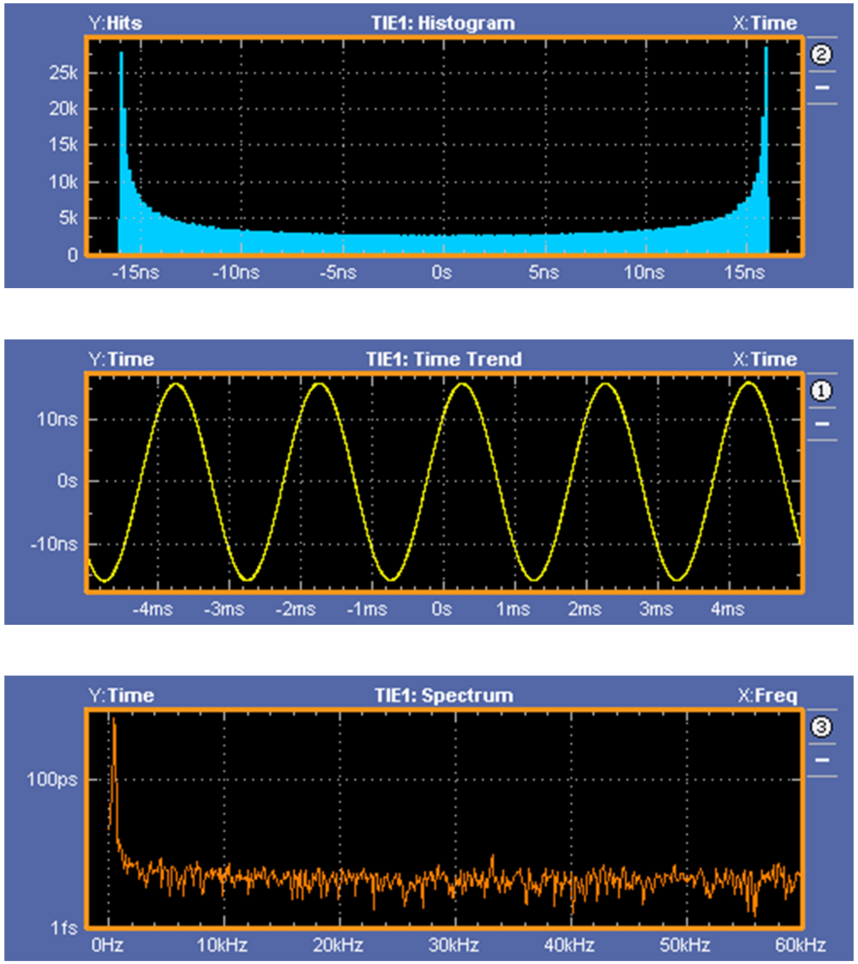
Jitter Visualization

- Graphical views of jitter provide great insight into jitter behavior
  - **Histogram**:
    - Frequency of Occurrence versus Jitter Amplitude
    - To a practiced eye, allows quick assessment of RJ vs. DJ, and how the DJ is distributed
  - **Time Trend**:
    - Jitter Amplitude versus Time
    - Reveals PLL transient behavior
    - Allows quick diagnosis of clock recovery failures
  - **Spectrum**:
    - Jitter Amplitude versus Frequency
    - Deterministic jitter that is not discernable in other domains is easily seen
    - Root cause can be traced back due to spectral signature

Jitter Visualization: Examples I

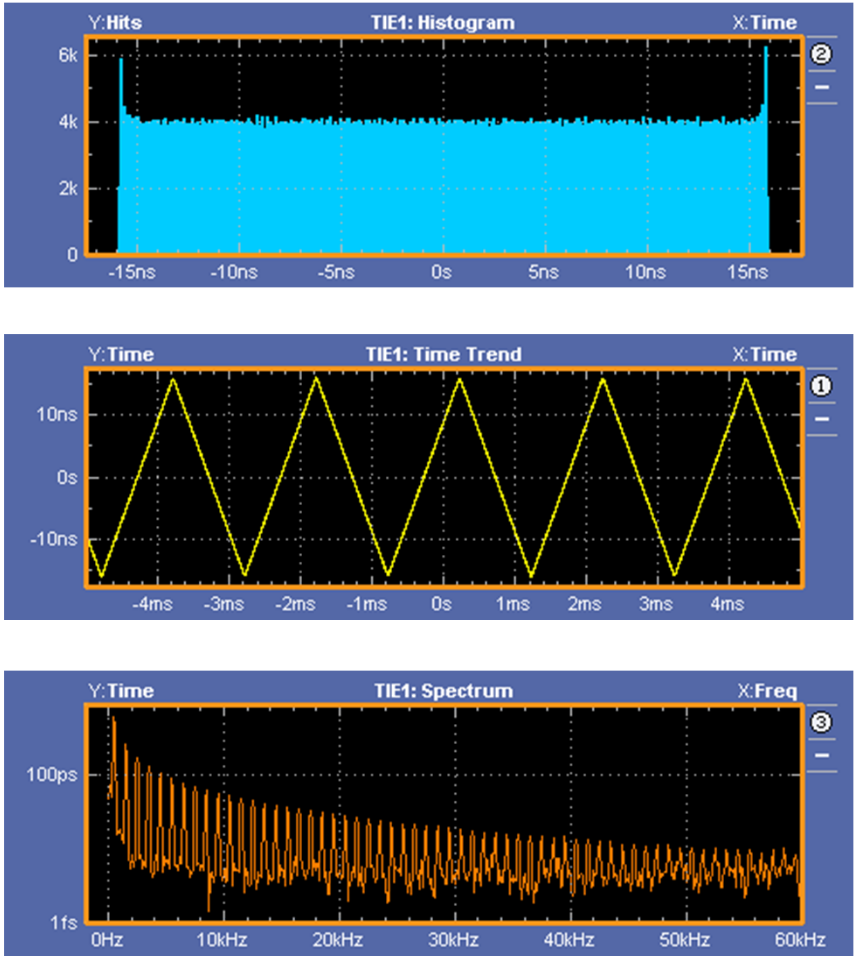


Gaussian Random Noise

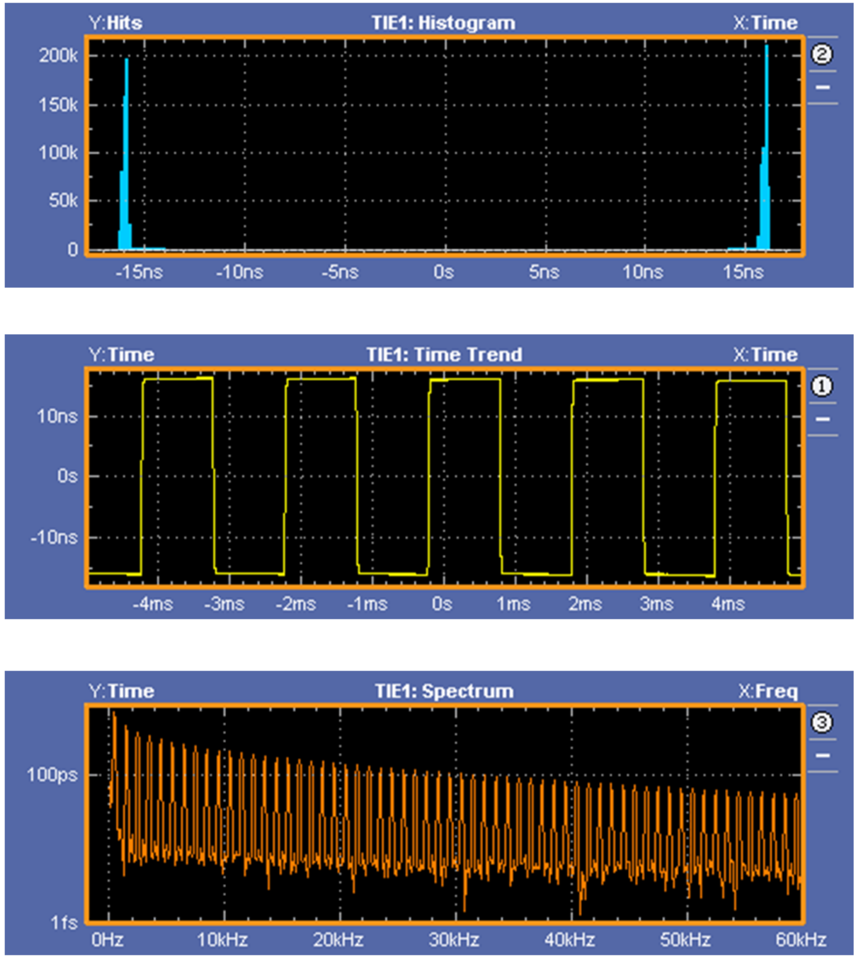


Sinusoidal Jitter

Jitter Visualization: Examples II

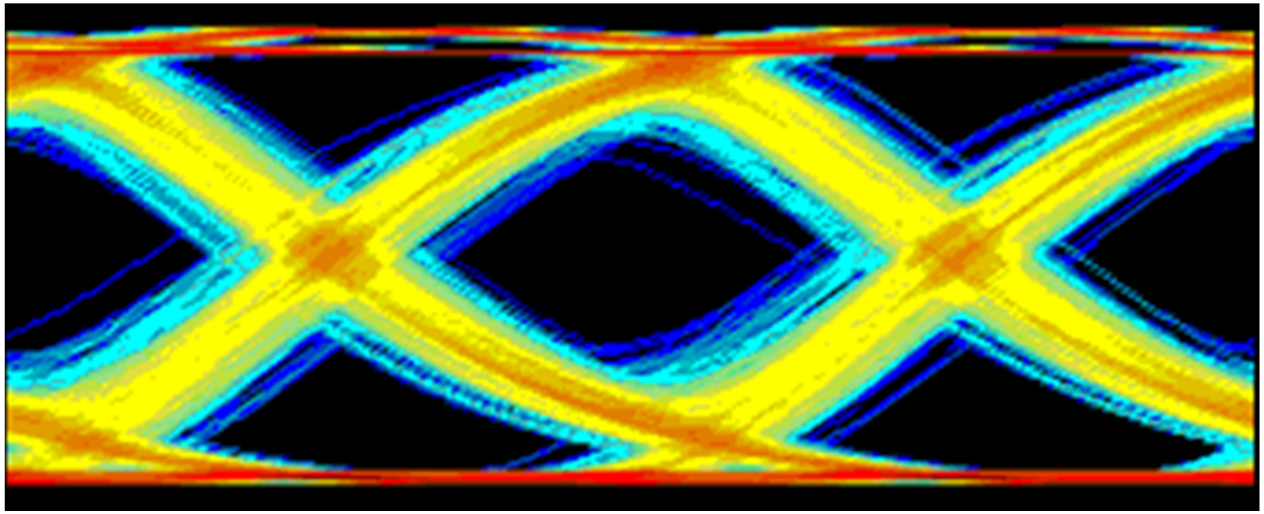


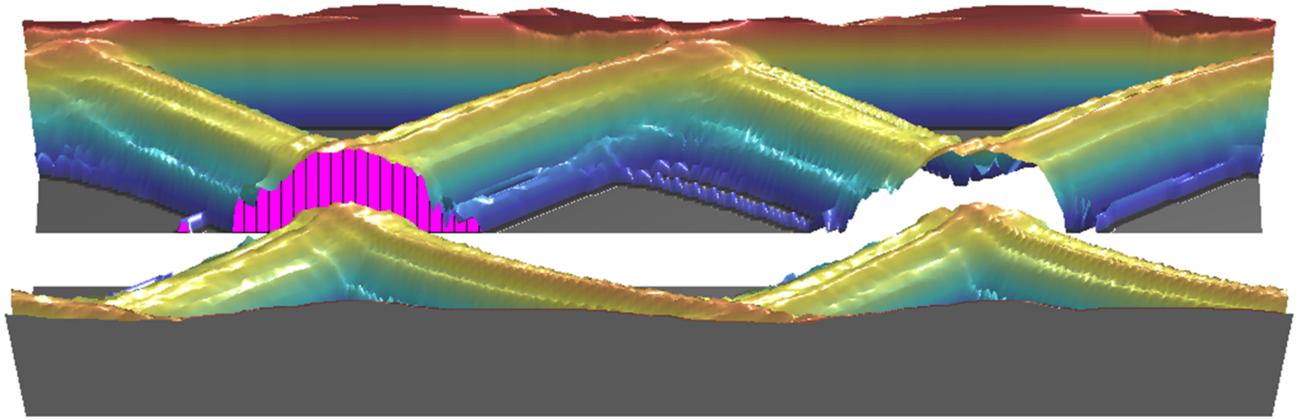
Triangle Wave Jitter



Square Wave Jitter

Another View of TIE, Relative to an Eye Diagram





Demo: Jitter Basics

Visualization, Clock Recovery

Advanced Jitter - Decomposition

Rj / Dj Separation, Dual-Dirac

Motivations for Jitter Decomposition

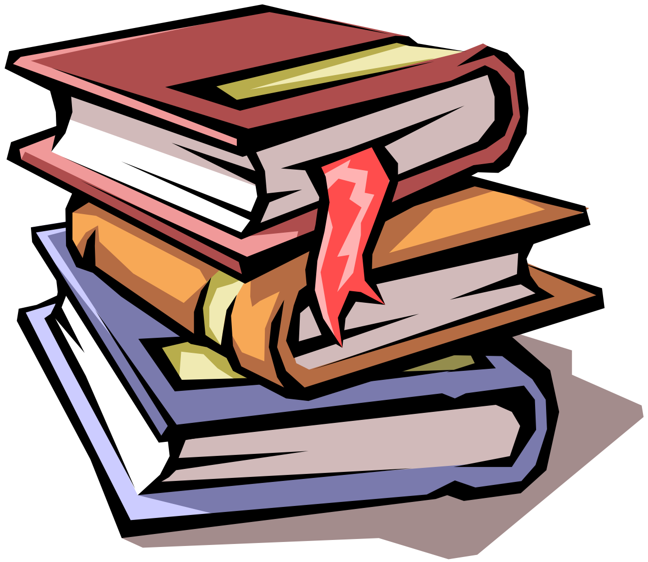
- **Speed**: Directly measuring error performance at 1e-12 requires directly observing MANY bits (1e14 or more). This is time consuming! Extrapolation from a smaller population can be done in seconds instead of hours.

- **Knowledge**: Jitter decomposition gives great insight into the root causes of eye closure and bit errors, and is therefore invaluable for analysis and debug.

- **Flexibility**: Already have a scope on your bench? You can do Jitter@BER measurements without acquiring more, perhaps somewhat specialized equipment.

Common Terms

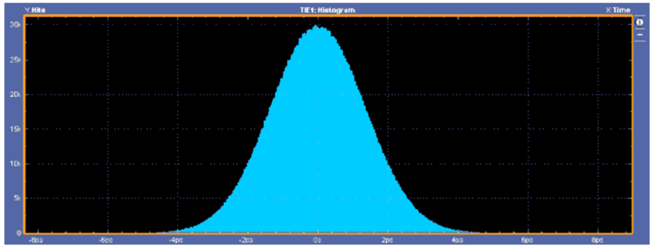
- Bit Error Rate (BER)
- Total Jitter ~ (TJ or TJ@BER)
- Random Jitter (RJ)
- Deterministic Jitter (DJ)
  - Periodic Jitter (PJ)
  - Sinusoidal Jitter (SJ)
  - Duty Cycle Distortion (DCD)
  - Data-Dependent Jitter (DDJ)
  - Inter-Symbol Interference (ISI)
- Eye Width @BER
  - versus Actual or Observed Eye Width



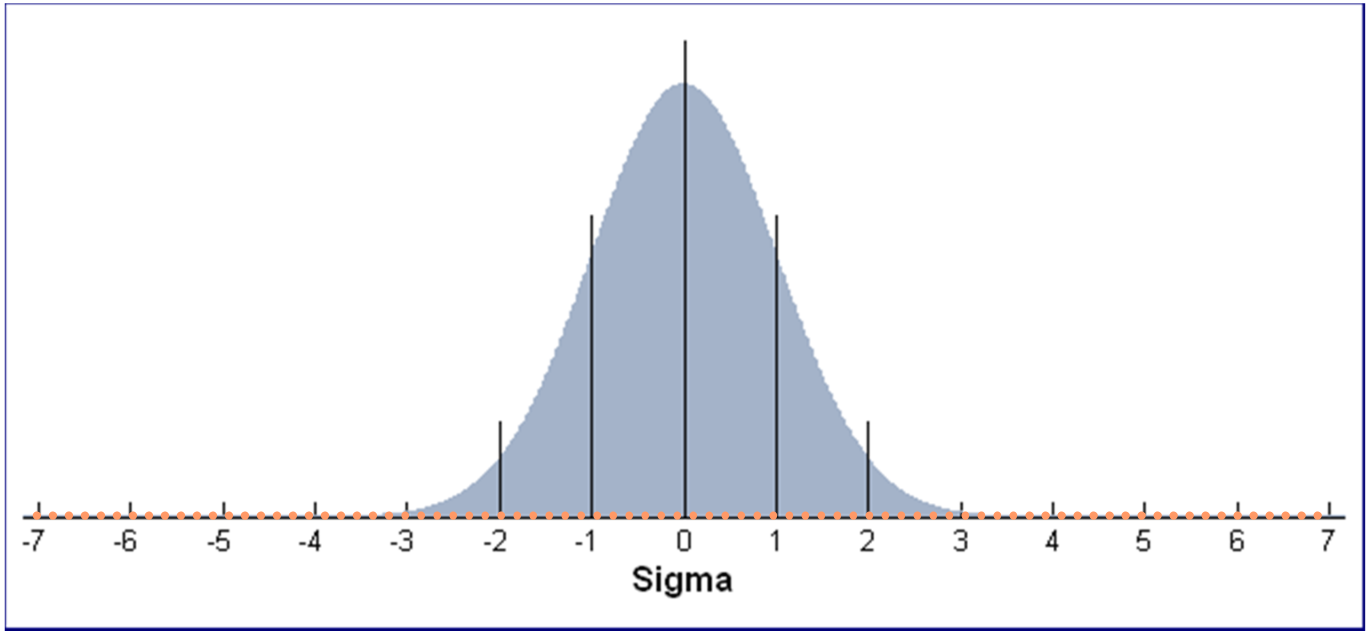
Bit Error Rate (BER), Total Jitter (Tj)

- BER: Bit Error Rate/Ratio
  - A metric used to specify data link quality
  - Defined as the ratio of erroneous bits to total bits.
  - Example: In 10^{12} Bits, only one error is allowed → BER = $1*10^{-12}$
- Total Jitter (Tj)
  - The jitter expected or measured at a specified BER.
  - Tj is generally known as "Jitter @ BER"
  - Example: Tj @ 10^{12} => The total jitter measured at a 10^{-12} bit error ratio

Random Jitter (RJ)

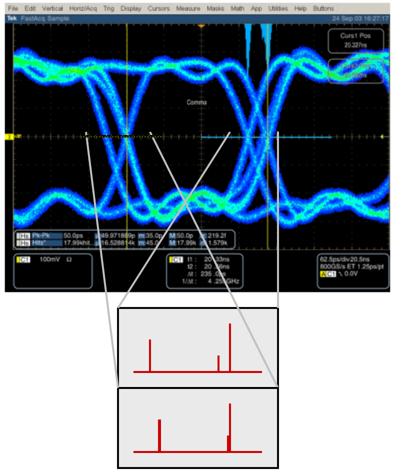


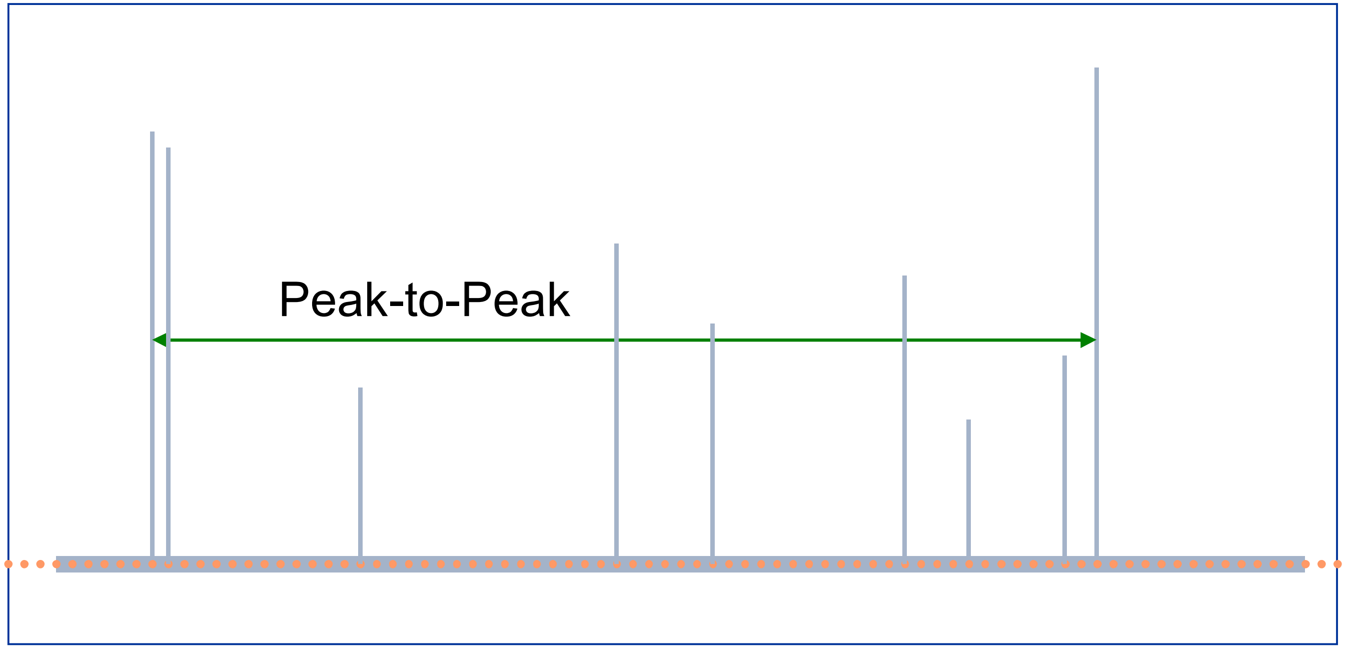
- Jitter of a random nature is assumed to have a Gaussian distribution (Central Limit Theorem)
- Histogram (estimate) ↔ pdf (mathematical model)
- Peak-to-Peak = … unbounded!



Deterministic Jitter (DJ)

- Deterministic jitter has a bounded distribution: the observed peak-to-peak value will not grow over time
- Histogram = pdf (close enough)





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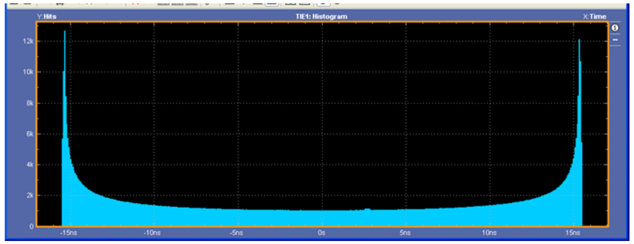
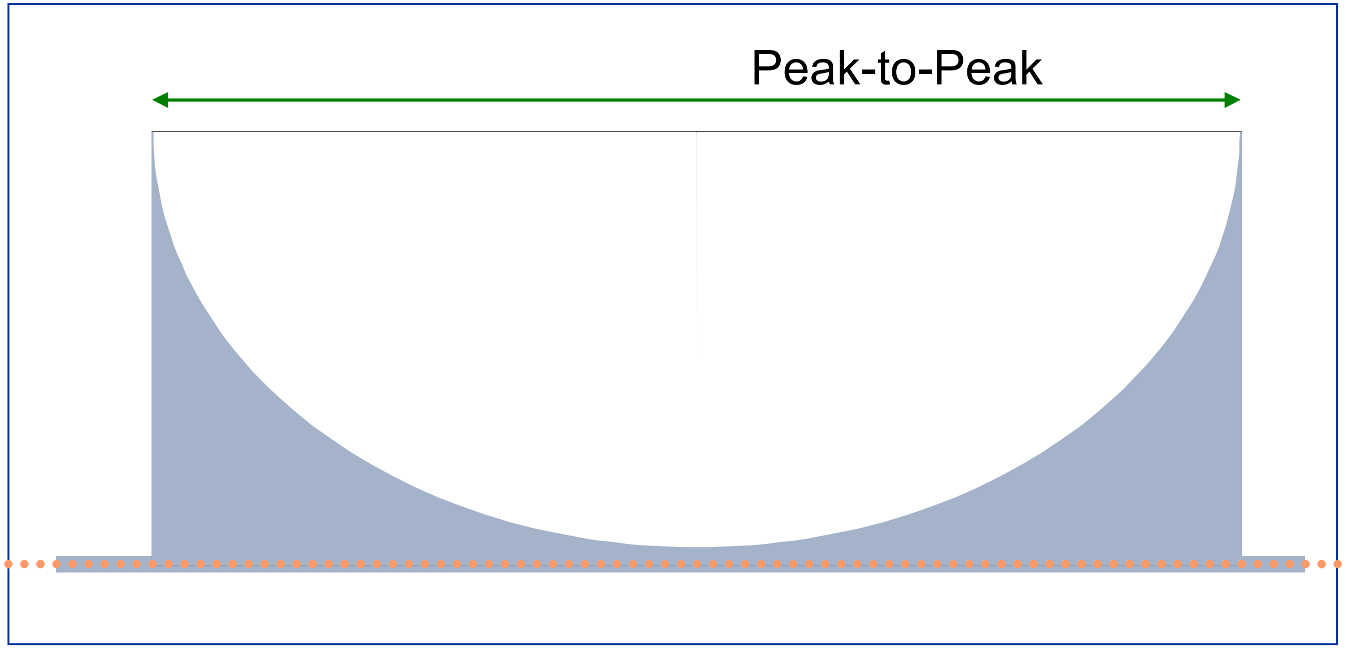
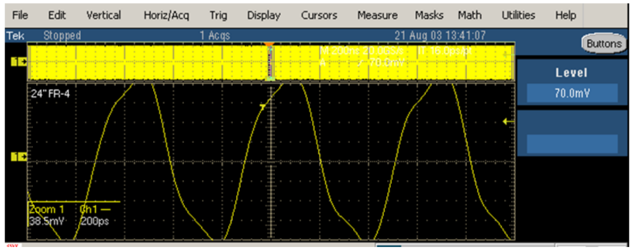
Periodic Jitter (PJ, SJ)



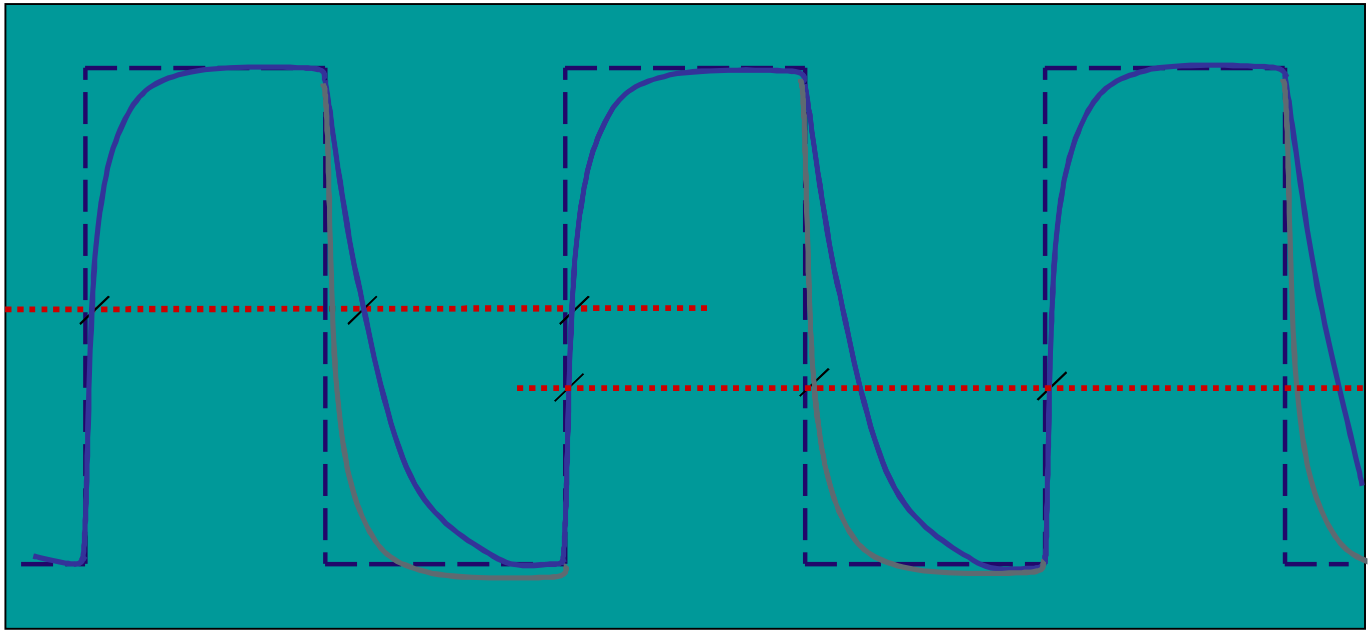
- TIE vs. time is a repetitive waveform
- Assumed to be uncorrelated with the data pattern (if any)
- Sinusoidal jitter is a subset of Periodic Jitter



Duty Cycle Distortion (DCD)



- pdf consists of two impulses (“dual dirac”)
- Asymmetrical rise-time vs. fall-time
- Non-optimal choice of decision threshold



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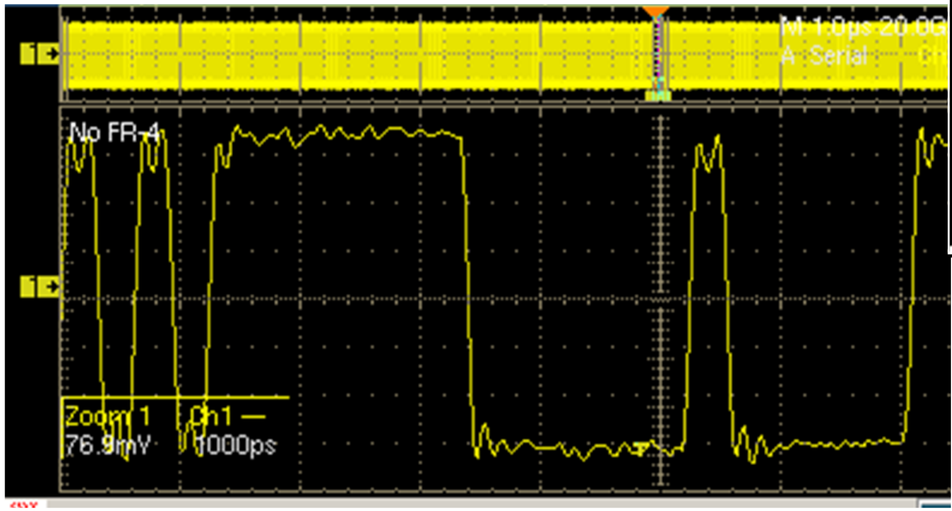
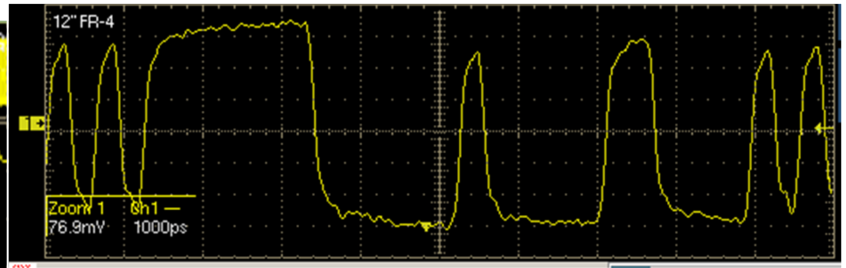
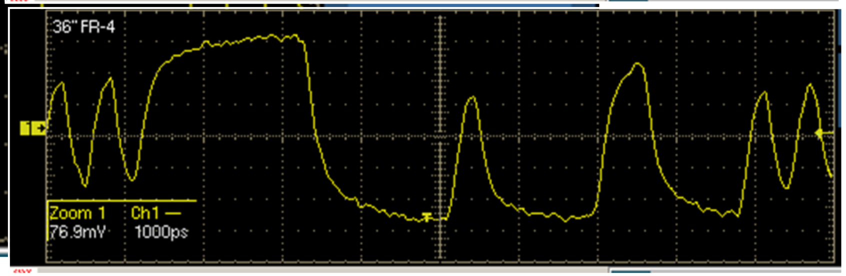
Inter-Symbol Interference

- ISI or DDJ or PDJ – used interchangeably
- Characterizes how the jitter on each transition is correlated with specific patterns of prior bits
  - Due to the step response of the system
  - Due to transmission line effects (e.g. reflections)







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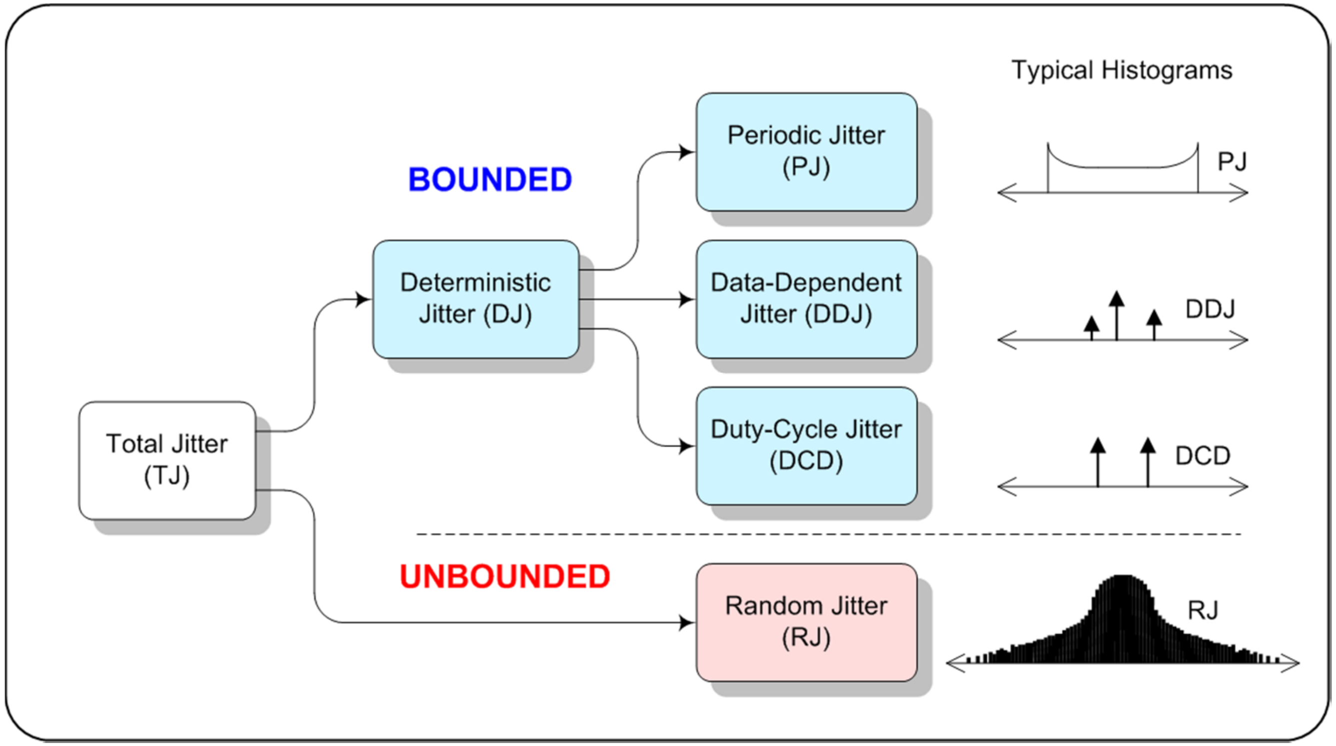
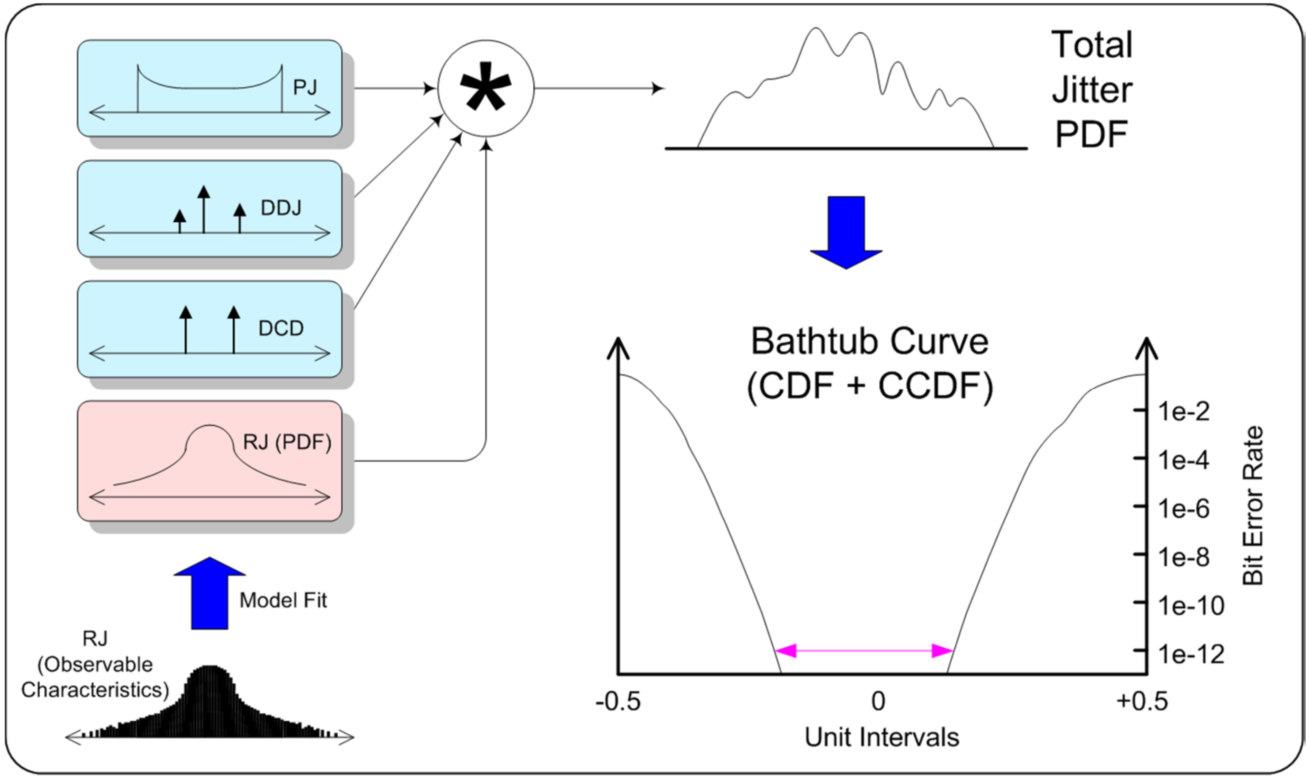
Advanced Jitter Analysis Methodology - Part I

- Jitter Analysis (Decomposition)
  - Total observed jitter (in the form of TIE) is broken down into its components, based on known properties of the signal
  - This is a parametric model fit, so the answer depends on the jitter model



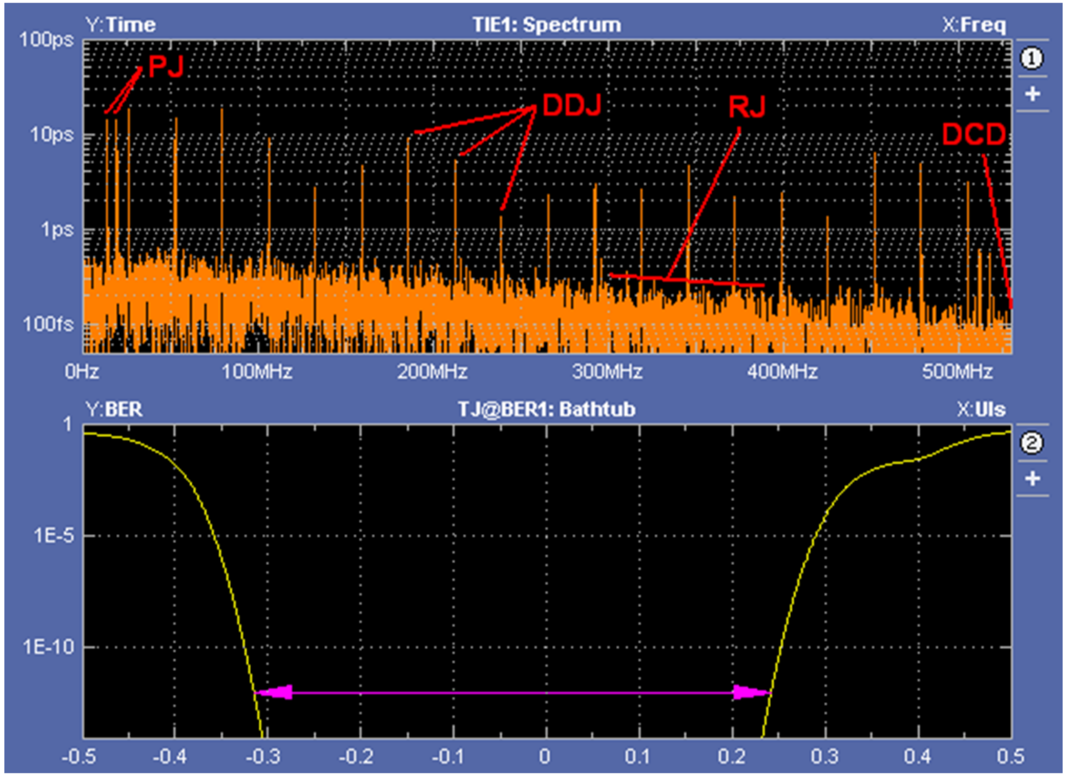
Advanced Jitter Analysis Methodology - Part II

- Jitter Synthesis (Reconstruction / Extrapolation)
  - The observed RJ histogram is converted to an RJ model via parameter fit
  - The jitter components are reassembled via convolution to find the Total Jitter PDF
  - The PDF is integrated twice (once from the left, once from the right) to create the Bathtub Curve



Tektronix Real-Time Rj/Dj in a Nutshell

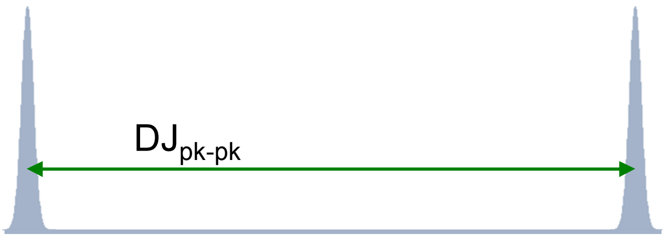
- Start with TIE
- Perform an FFT
  - Determine frequency and pattern rate
  - Sum pattern related bins
  - Sum unrelated periodic bins
  - Measure RMS of remaining bins; compute Sigma of RJ
- Reconstruct Total Jitter PDF
- Create Bathtub



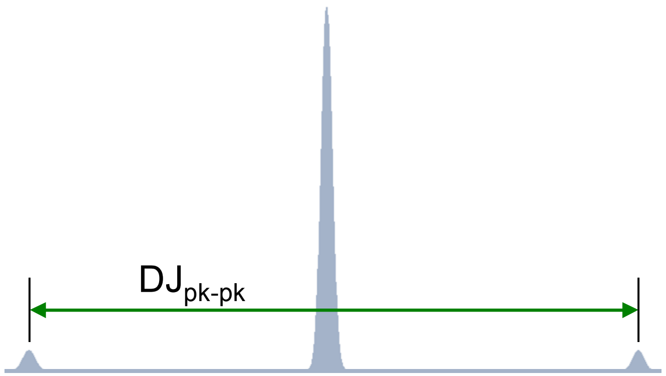
Dual Dirac Jitter: Motivation

- In the early days of Rj/Dj analysis, systems were sometimes characterized by two parameters:
  - RJ (rms)
  - DJ (pk-pk)

- Consider two systems, each characterized by its jitter histogram:



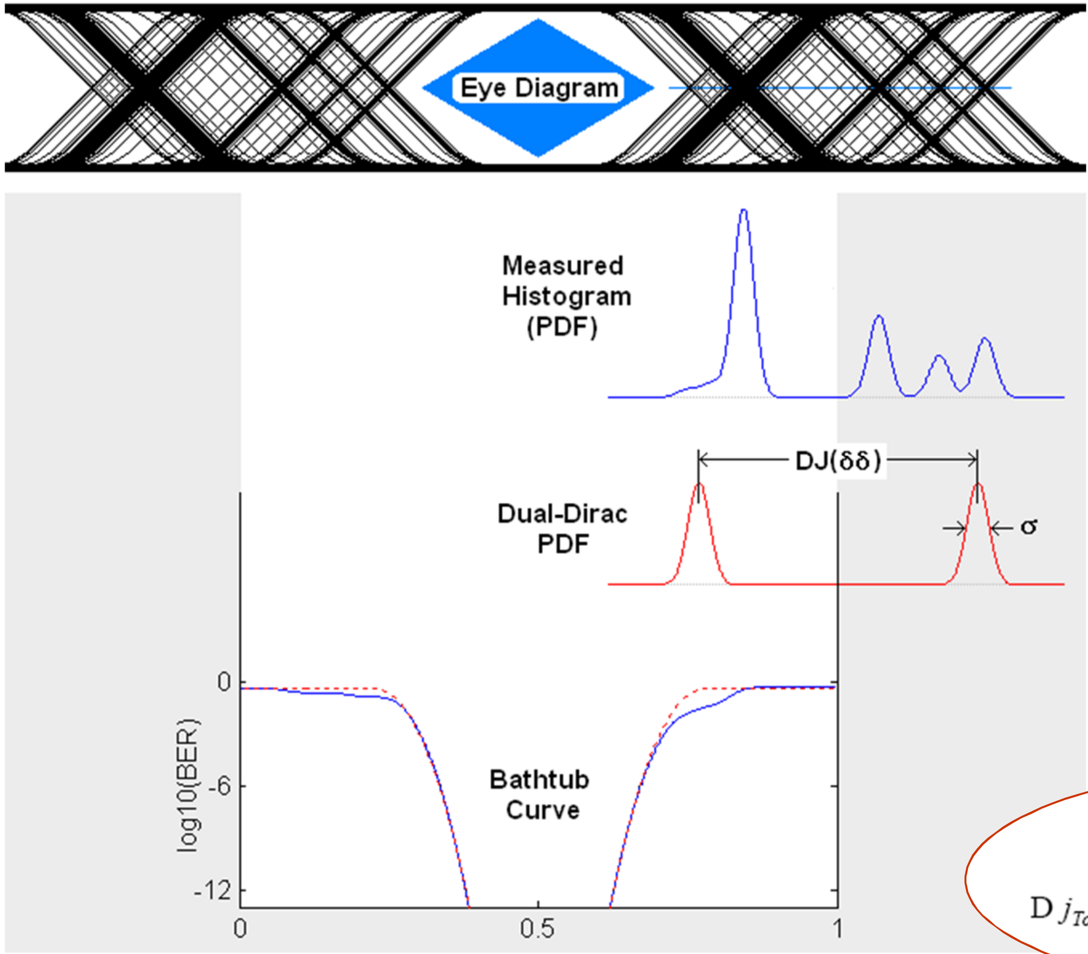
System 1



System 2

- System 1 and System 2 have the same RJ_{rms} and DJ_{pk-pk}, so they would be classified as equivalent. Yet they behave differently at low bit error rates. Clearly something had to change…

Dual-Dirac Jitter: General Implementation

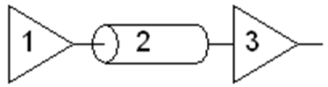


2-Parameter Model

- Sigma (σ)
- DJ(δδ)

Benefit:

System analysis is greatly simplified…

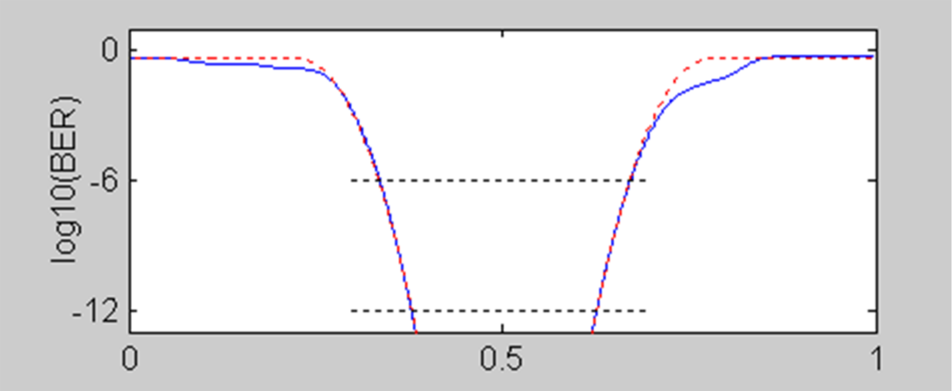


$$\sigma_{Total} = \sqrt{\sigma_1^2 + \sigma_2^2 + \cdots + \sigma_N^2}$$

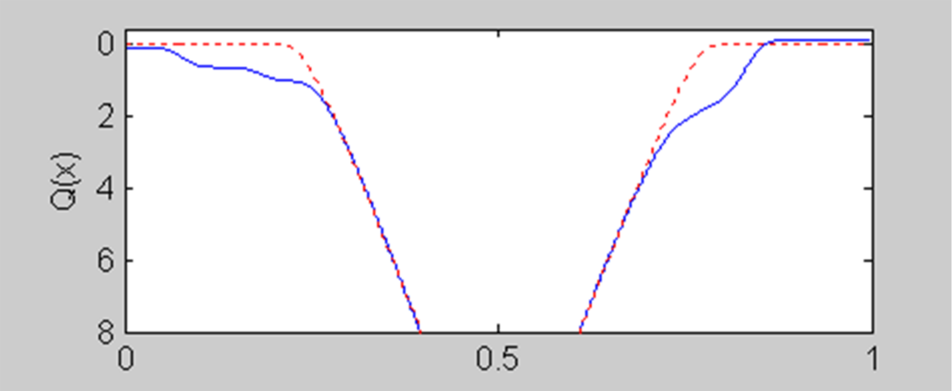
$$\mathrm{D}\,j_{Total}(dd) \approx \mathrm{D}\,j_1(dd) + \mathrm{D}\,j_2(dd) + \cdots + \mathrm{D}\,j_N(dd)$$

Dual-Dirac Jitter: Fibre-Channel vs. PCI-Express

- Fibre-Channel Model
  - Pick two BER reference levels
  - Adjust σ and $DJ_{pk\text{-}pk}$ until the dual-dirac bathtub passes through the same points as the measured bathtub, at the chosen reference levels



- PCI-Express Model
  - Plot the eye opening against Q(x) instead of against BER, where Q(x) is a linear transform on BER for which gaussian tails become straight lines
  - On this scale, the slope of the asymptotes is exactly the value $1 / \sigma$



Tektronix DPOJET Overview

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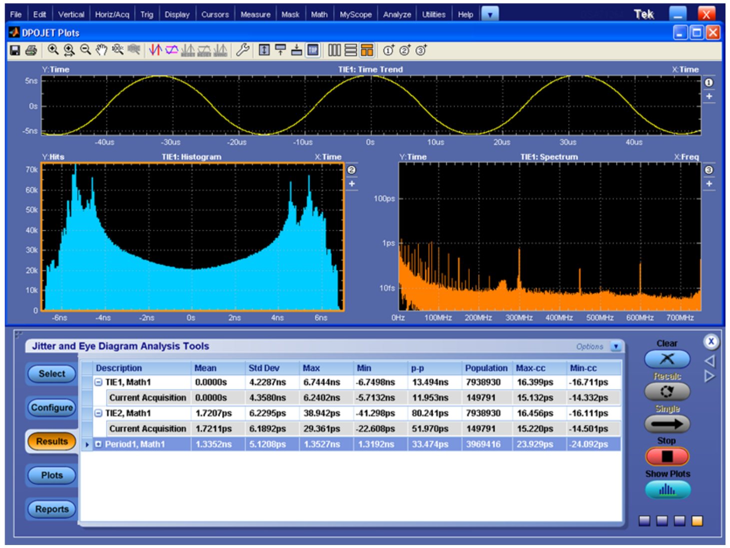
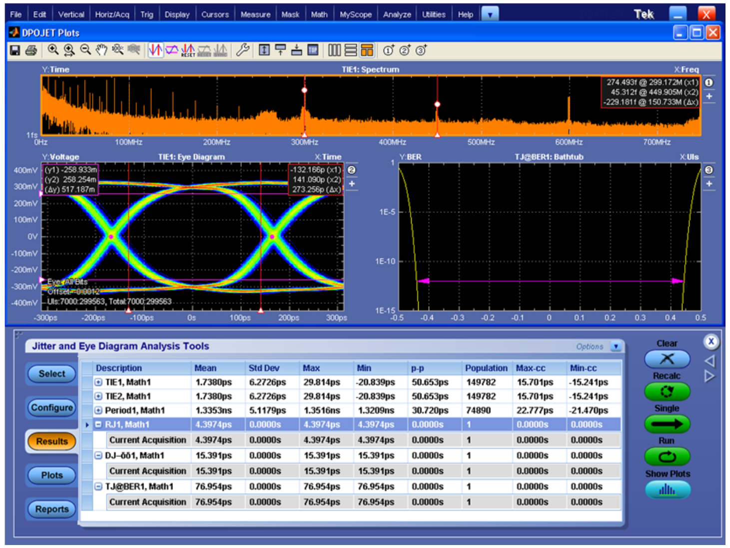
Agenda

- DPOJET Overview
- DPOJET Control Structure Review
  - Panels & *Menus*
  - Results, Plotting
  - Reports, Logging
  - Preferences
  - Limits Testing & Plans for the Future
- DPOJET Configuration
  - Edges and Auto Clock/Data Selection
  - RJ/DJ, Filters, General, Global
  - Clock Recovery Choices
  - Plot Types
    - Extra Configuration (on the plots and under the selections)
    - Layout, Masks, Scales, and staying on Top
- DPOJET Eye Diagrams
  - CDR Control of Eye Placement

DPOJET - Introduction

- DPOJET is Tektronix' next generation Jitter, Timing and Eye Diagram Analysis Tool.
- Available in two option levels:
  - **Essentials** for DPO7000 instruments provides basic timing analysis, priced to be affordable on lower cost instruments.
  - **Advanced** for DPO7000 and DPO70000 instruments provides full capability, Priced according to bandwidth and appropriate mask testing support (higher bandwidth instruments support a broader range of standards).
- DPOJET combines the functionality of industry standards TDSJIT3 and TDSRTE into one integrated instrument enhancement.





Tektronix

DPOJET - Overview

- Extensible Measurement Interface (internal feature)
  - Allows Tektronix to better support new or rapidly changing standards
- One-Touch Jitter Measurement Wizard
  - Allows Users to arrive at full jitter decomposition results with a single button press.
- Jitter Measurement Guide
  - Allows Users to select from common measurements in a guided fashion, allowing consistent results from technicians and engineers new to jitter analysis.
- User Masks and Compliance Test Limits
  - Allows Users to add new tests complete with eye masks and measurement test limits allowing full Pass/Fail testing.
- Selectable Jitter Decomposition
  - Allows Users to select from current TJ(BER) evaluation algorithms:
    - Dual-Dirac according to T11
    - Dual-Dirac according to PCI-Sig
    - or fully convolved used in TDSJIT3 (most accurate).

DPOJET – Overview *(cont'd)*

- Arbitrary Pattern Analysis
  - Allows Users to perform accurate jitter decomposition on a wide variety of signal types without regard to known or repeating patterns.
- Selectable Measurement Filters
  - Allows Users to select high and low pass filters on measurements to exclude jitter from known or compensated sources (e.g., SSC tracking).
- Jitter Transfer Function
  - Allows Users to directly view the Jitter Transfer between two signals.
- Patented PLL Emulation for Clock Recovery
  - Allows Users to model measurements according to expected hardware design performance.
- Enhanced (& Patented) Real-Time Eye Diagram Plotting
  - Allows Users to view eye-diagrams from single acquisition waveforms.

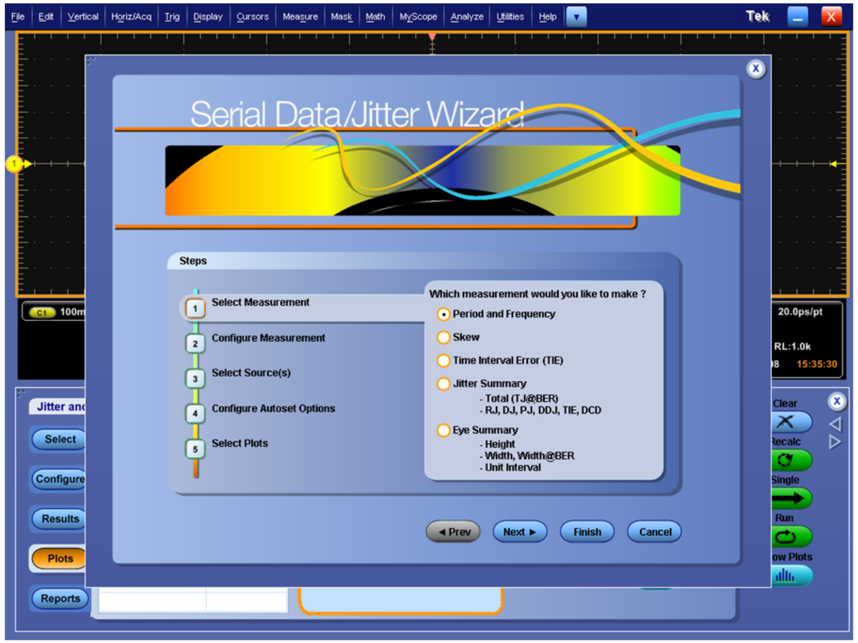
DPOJET – User Interface

- Measurement Selection
  - Period/Frequency
  - Jitter
  - Timing
  - Eye Diagram
  - Amplitude
  - More…

- Users can select measurements from any source
  - Channel, Math, Ref
- Users can select the same measurement on multiple channels:
  - Period(Ch1), Period(Ch2), Period(Ch3), Period(Math1)
  - TIE(CH1) TIE(CH1)
    e.g., this is useful comparing the effects of different CDR configurations for each measurement source

DPOJET - Wizards

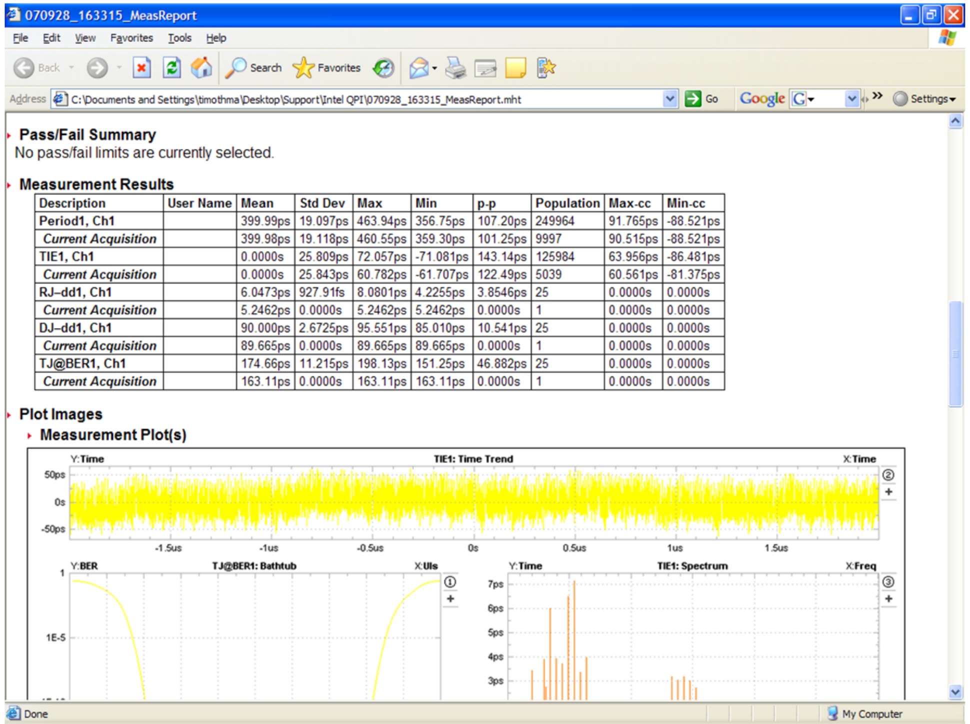
- DPOJET provides two measurement Wizards
- One Touch Jitter
  - Provides the easiest to use jitter analysis available
  - Select One Touch Wizard and DPOJET configures the available source with a selection of the most common jitter measurements and plots… all in one step.
- Serial Data Guided Setup
  - More configurable wizard that guides users through the jitter setup process
  - Select from Period jitter, RJ/DJ breakdown, Eye analysis, and more.



Tektronix®

DPOJET - Reports

- DPOJET creates reports that include a complete report of the tests being performed.
  - Measurement results
  - Summary and detail plots
  - Oscilloscope screen image
  - Pass/fail test results
  - Measurement and instrument configuration summary
- DPOJET reports are in open HTML format, saved as HTML archives so one file includes text, tables, and images, and allows easy report management and distribution.



Pass/Fail Summary

No pass/fail limits are currently selected.

Measurement Results

Description	User Name	Mean	Std Dev	Max	Min	p-p	Population	Max-cc	Min-cc
Period1, Ch1		399.99ps	19.097ps	463.94ps	356.75ps	107.20ps	249964	91.765ps	-88.521ps
Current Acquisition		399.98ps	19.118ps	460.55ps	359.30ps	101.25ps	9997	90.515ps	-88.521ps
TIE1, Ch1		0.0000s	25.809ps	72.057ps	-71.081ps	143.14ps	125984	63.956ps	-86.481ps
Current Acquisition		0.0000s	25.843ps	60.782ps	-61.707ps	122.49ps	5039	60.561ps	-81.375ps
RJ–dd1, Ch1		6.0473ps	927.91fs	8.0801ps	4.2255ps	3.8546ps	25	0.0000s	0.0000s
Current Acquisition		5.2462ps	0.0000s	5.2462ps	5.2462ps	0.0000s	1	0.0000s	0.0000s
DJ–dd1, Ch1		90.000ps	2.6725ps	95.551ps	85.010ps	10.541ps	25	0.0000s	0.0000s
Current Acquisition		89.665ps	0.0000s	89.665ps	89.665ps	0.0000s	1	0.0000s	0.0000s
TJ@BER1, Ch1		174.66ps	11.215ps	198.13ps	151.25ps	46.882ps	25	0.0000s	0.0000s
Current Acquisition		163.11ps	0.0000s	163.11ps	163.11ps	0.0000s	1	0.0000s	0.0000s

Plot Images

Measurement Plot(s)

DPOJET – Configuration

- Configuration
  - Measurement Parameters
  - Source Vert Scale Autoset
  - Source Horiz Autoset
  - Ref Levels
  - Gate/Qualify
  - Population Limit
- Users configure each Source and Measurement independently
  - Each source has its own settings
  - Each measurement has its own settings
  - Convenient Apply to All to ensure measurements use common setups, when needed.

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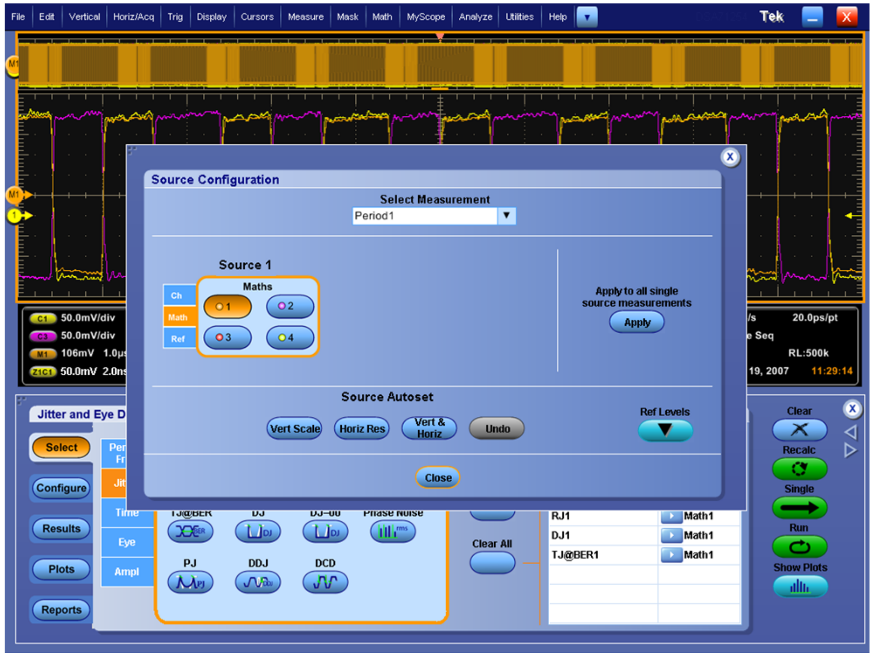
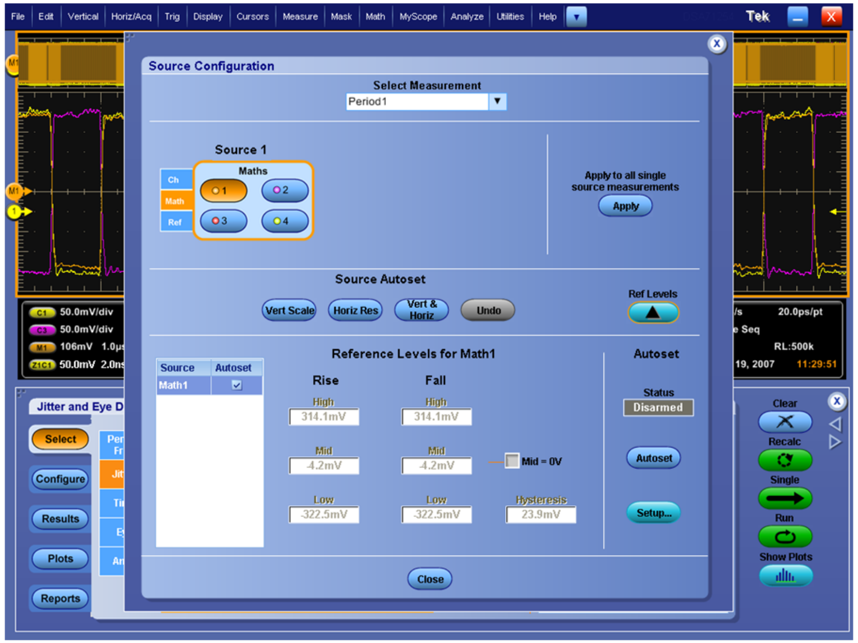
DPOJET – Autosets

- Vertical Autoset
  - Intended to maximize vertical dynamic range
  - Each source can be set independently
- Horizontal Autoset
  - Adjusts horizontal settings to ensure reliable results based on signal risetime
- General purpose automatic settings to allow users to get to answers as fast as possible.



DPOJET – Reference Levels

- Sets thresholds used for making measurements
  - Each source has its own settings for rising and falling edges
  - Autoset-Setup allows changing levels by percentage (e.g., 10-90%)
  - Autosets all active sources
- Selectable autoset methods for cases where signal is not typical:
  - Min-Max
  - Low-High (pulse)
  - Low-High (eye)
  - Auto
    for example a signal with dominant tri-state regions will average lower than typical NRZ waveforms. In this case Min-Max will result in a better choice of reference levels



Hysteresis is an important setting, especially in noisy environments …

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DPOJET – Gates and Qualifiers

- Gate
  - Measurements are made only inside gated region
  - Gate by Cursor
  - Gate by Zoom
  - Gate by Search
  - Limits single shot population hence Rj/Dj capability
- Qualify
  - Measurements are made only when Qualify input has transitions and state meets criteria

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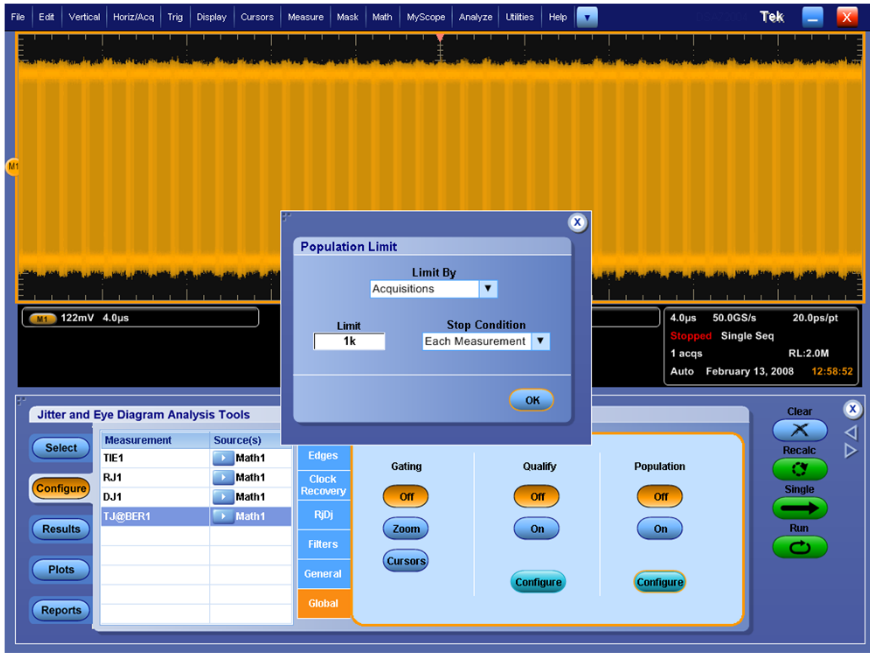
DPOJET – Population Limit

- Sets population limit for making measurements
  - Population can be by measurements or by acquisitions
  - Measurement stops when limit reached by last measurement to reach the limit or when each measurement reaches the limit.
  - Limits in Run mode (continuous), acquisitions stop when population limit reach



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DPOJET – Summaries

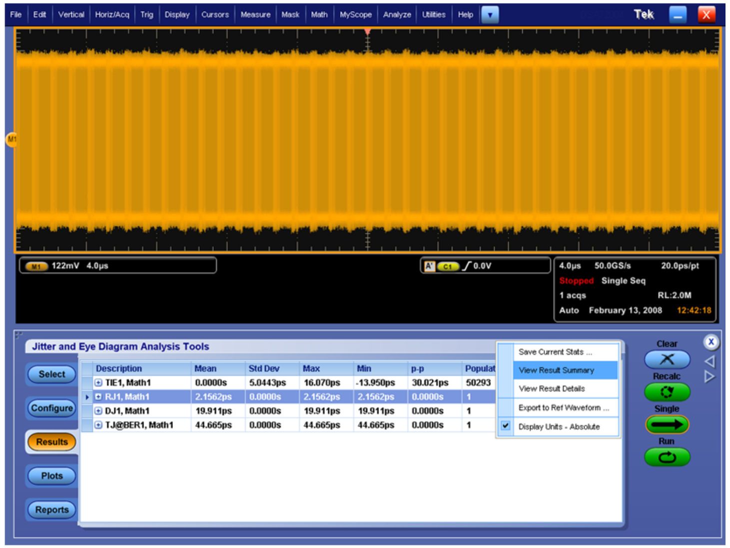
- Shows a summary of measurements, their configurations and reference levels
  - Handy place to review how the software is configured
  - Summaries of measurements, setups, and configurations are available.
  - Summaries can be included in reports, viewed on screen, or saved to disk.

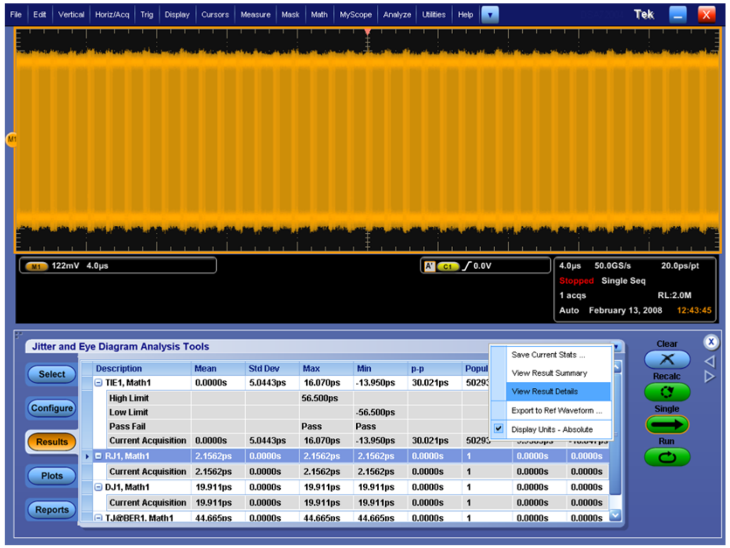
DPOJET – Results Views

- Results are displayed in one panel, but can be expanded to show additional details
  - Summary View
  - Detail View

- Summary view shows statistical results from all acquisitions in a single vertical table

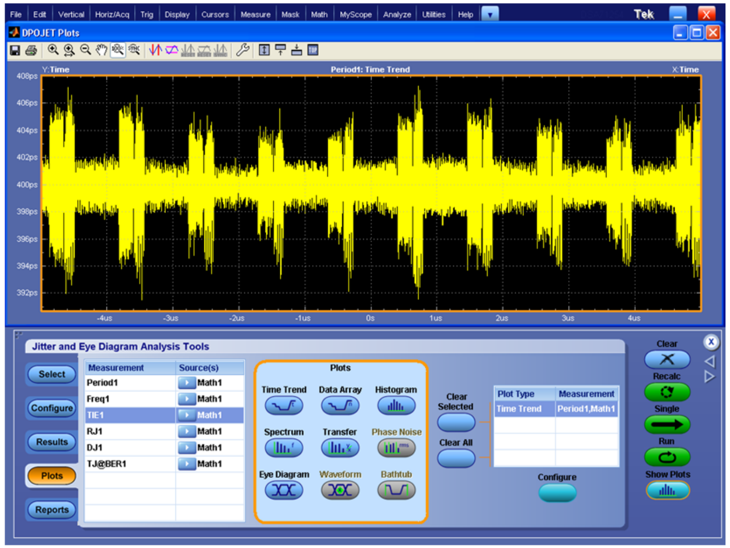
- Detail view shows current acquisition and all acquisition statistics, plus limits information is Pass/Fail testing is enabled.





DPOJET – Plot Creation

- Users can create up to 4 plots
  - Plots appear in a Summary Window
  - The Summary Window can be dragged to second monitor
  - Once created, plot and scope views are manipulated using in-window controls or normal Windows controls
  - Each plot has independent X and Y cursors with readouts
  - Plots autoscale by default, but can be manually scaled, and zoomed. Plots retain settings while running.
  - Data can be exported to REF memories for 1:1 correlation
  - Use with Worst Waveform logging for in-depth analysis



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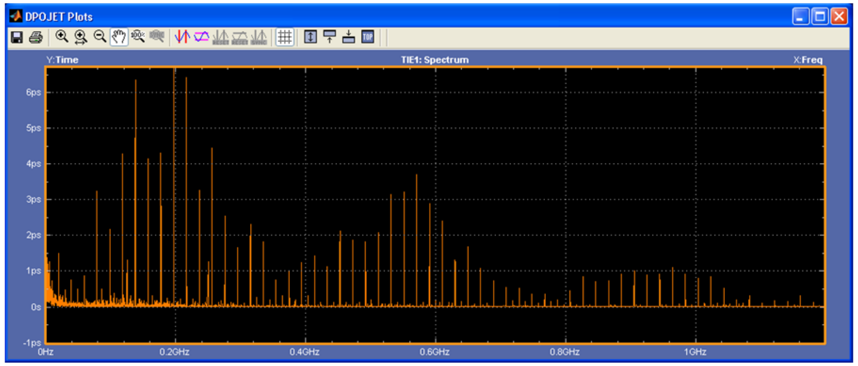
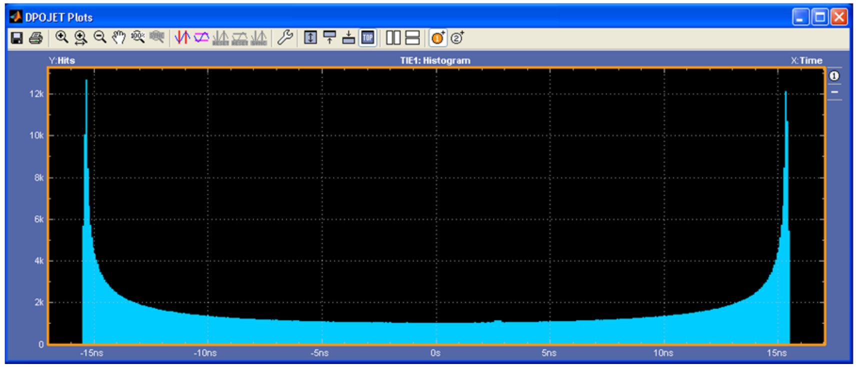
DPOJET – Plot Window Controls

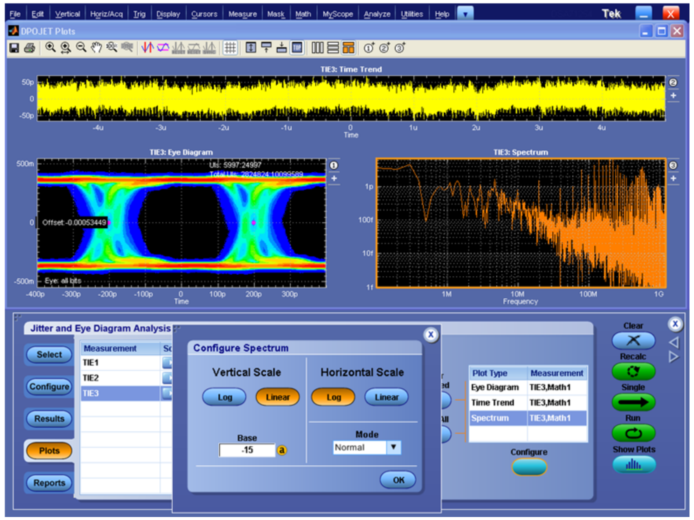
- Plot windows controls
  - Save Figure (Image or Data)
  - Print Plot
  - Zoom In
  - Zoom Horizontal
  - Zoom Out
  - Pan
  - Zoom Reset
  - Zoom Sync
  - Vert Cursors/Horiz Cursors
  - Reset Vert Cursors/Horiz Cursors
  - Sync Cursors
  - Plot Tools (Set Scales)
  - Position Full/Top/Bottom
  - Always on Top
  - Select Summary View
  - Select Detail View

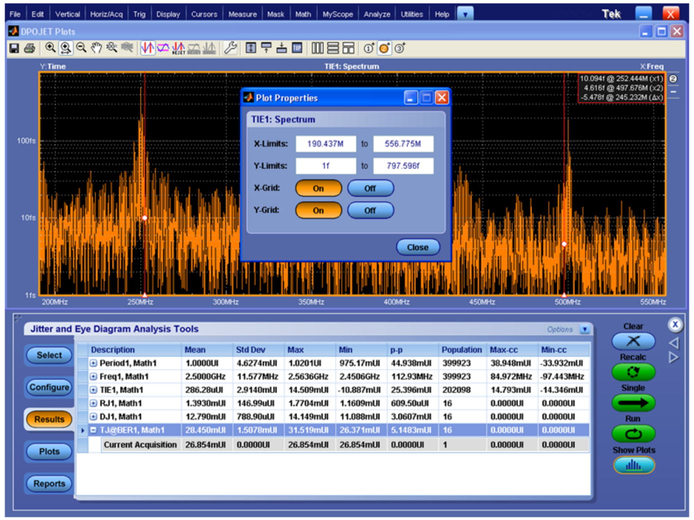




DPOJET – Plot Configuration

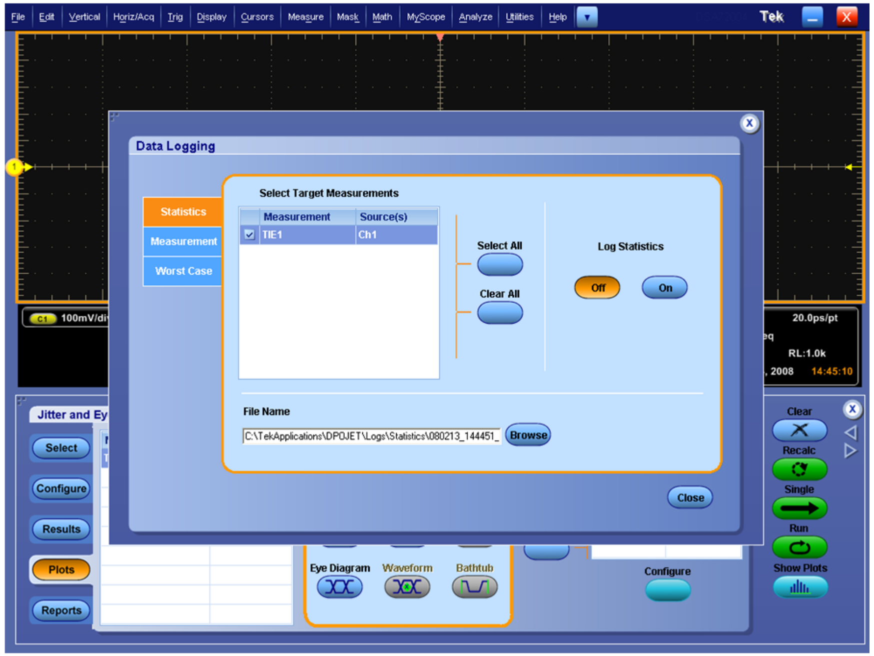
- Plots are also configured independently
  - General data format and config details from plot Configuration panel (in plot select), e.g.
    - Linear / Log
    - Bar / Vector
  - Plot window graphic details in the plot Tools panel (in window)
    - Vertical scale
    - Horizontal scale
    - Grid





DPOJET – Data Logging

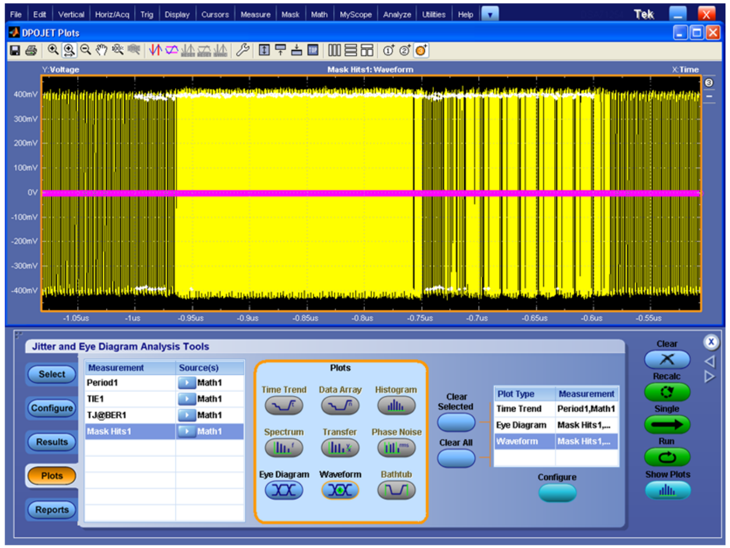
- Logging comes in three flavors
  - Statistics Logging
  - a history of each measurement result and statistics
  - Measurement Logging
  - a snapshot of the current measurements plus the full data array that was used
  - Worst Waveform Logging
  - a snapshot of the waveform that contained the worst measurement

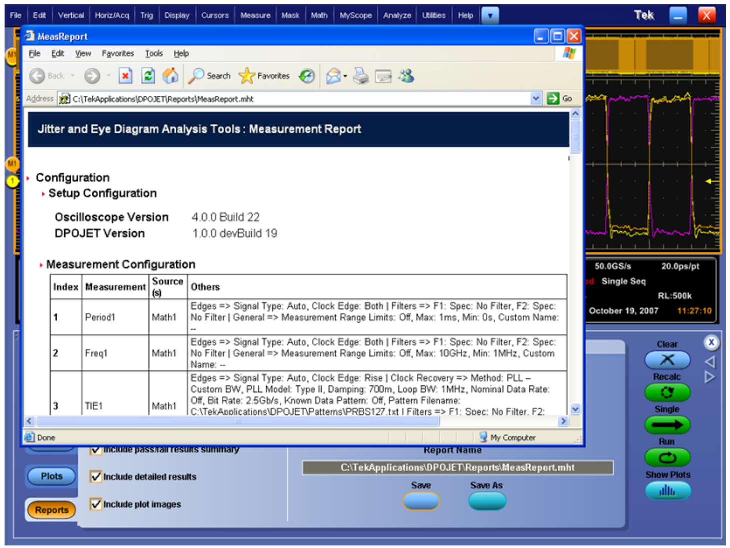


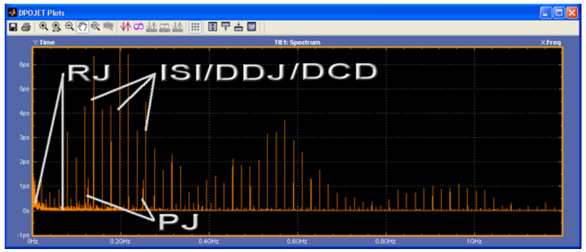
logging measurements takes huge amounts of disk space …

DPOJET – Analysis

- Patented Eye Diagrams
- Patented RJ/DJ/TJ(BER) Analysis
- Patented Software PLL Models
- DPOJET innovations have a strong history of firsts. Building on industry standard techniques from TDSJIT3 and TDSRTE, DPOJET brings together the most used application tools.
- Complete Eye Diagram Analysis, Jitter Decomposition, Data Logging, Limits Testing, and Data Reporting in open formats. DPOJET is the one stop shoppers product for Jitter and Eye Diagram Analysis.







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DPOJET – Making Good Measurements

- DPOJET requires only a basic understanding of the oscilloscope acquisition system to get the best and most accurate results.

- Vertical Amplitude, Horizontal Scale and Sample Rate are key factors in repeatable Jitter an Eye Diagram measurements
  - **Vertical Scale:** Always attempt to maximize the vertical amplitude to 6 divisions or more. This minimizes the effect vertical noise.
  - **Horizontal Scale:** Larger populations are better. *For Rj/Dj, 100 repeats of the applied signal pattern must be captured in a single acquisition.* The tradeoff of larger populations is acquisition time grows with record length. Alternate methods for arbitrary data patterns are available, but also have requirements to acquire adequate data for proper analysis.
  - **Sample Rate:** *You must capture at least two to three sample points on measured edges – five points are preferred. This means that to measure a circuit with 100ps risetimes, 50ps/pt is the minimum sample interval you can use. A 200ps edge requires 100ps/pt, but 50ps/pt is better.*
  - **Using Sin(x)/x** interpolation mode, IT mode in the scope, or Sin(x)/x in DPOJET can help by providing interpolated edge resolution.

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  - Edges and Auto Clock/Data Selection
  - RJ/DJ, Filters, General, Global
  - Clock Recovery Choices
  - Plot Types
    - Extra Configuration (on the plots and under the selections)
    - Layout, Masks, Scales, and staying on Top
- DPOJET Eye Diagrams
  - CDR Control of Eye Placement

DPOJET Menu and Panel Secrets – Revealed!

- Analyze Menu
  - Has all the selects, configure, results, plots shortcuts…
  - Also has shortcuts to Summaries, Preferences, Limits, and more!
- Results Panel
  - The well hidden Options pull-down…
  - Plots no longer Export to Ref, results [Options ▾] does that now!
- Plot Layout and Scale Control !?!
  - Summary layout and detail views, and
  - The exceptionally well hidden Plot Tools…
  - Use both Plot Configuration – and – Plot Tools to control plots!
- Configuration Inheritance
  - Create and Setup one measurement, the rest follow suit…
  - Apply to All for many other cases, like RJ/DJ and CDR!

DPOJET Preferences

- Dual Dirac RJ/DJ Analysis
  - T11 and MJSQ
  - PCI-Express
- Edge Interpolation
  - Linear
  - Sin(x)/x (Sinc or non-linear)
  - Here or There: using IT vs. Sin(x)
- Logging and Export
  - Export: an Immediate operation: think “Do it now!”
  - Logging: an After the Fact operation: think “Do it later…”
- And then there’s Reporting
  - Save data in an industry standard open format **MHTML**

    *** MHTML stands for MIME HTML. File name extensions “*.mht*”**

Limits Testing and Compliance

- We Have Limits Files and Pass/Fail Testing Today
  - Limits Files are XML, require a few tricks, but they work well !
  - AE Level Support for new standards == Up to You to help customers
  - Example Limits.XML + Measurement Names.TXT are references
- Top Level Compliance Layer
  - Is under discussion… no clear direction, yet.
  - Expect interim offerings in the coming months… probably not turn-key.
- Partial Solutions Today
  - We have Masks for many standards
  - We have Setup Files and Limits Files for PCI-Express
  - We have the Standards Library from RT-Eye
  - We need volunteers to help port the measurements and limits files…

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Tektronix

Configuration Options

- Clock vs. Data Measurements
  - Clock is rise, fall, or both edges…
  - Data is always both edges
  - Auto-determined by edge density and period variations
  - When in doubt – set it manually – it can be confused!
  - SATA Data Test Pattern is 110011001100
    - guess what DPOJET selects for this pattern?
- RJ/DJ Analysis
  - Repeating Pattern
    - 100011011110111001000010001101111011100100001000110111…
  - Arbitrary Pattern
    - 1000110111101110010**1**001000110111101110010**0**1**1**01000110**1**01…
  - Window
    - 10001101111**0111**00100001000110111**1011**100100001000110111…
    - *1 1 2 2 3 4 3 5*
    - 100011011110111001000010001101111011100100001000110111…
  - Population
    - How many of each sub-pattern is averaged to find mean edge offsets

Tektronix

Clock Recovery Options

- CDR Methods
  - Constant Clock – Mean
  - Constant Clock – Median
  - PLL Standard BW
  - PLL Custom BW
  - Explicit Clock – Constant
  - Explicit Clock – PLL
  - Fixed
- Explicit Clock
  - Clock to Data Measurement
  - Clock edge positions Data in Eye Diagram
  - Can be multiplied
  - Can use PLL to smooth (high pass), including multiply
  - DDR, HDMI, DVI, FSB, etc.

Plot Selection Panel

- Histogram
- Time Trend (YT Data)
- Data Trend (Y Data)
- Bathtub (Time Domain BER Profile)
- Spectrum
- Transfer (Spectrum A / Spectrum B)
- Phase Noise (Spectrum in $\sqrt{Hz}$)
- Eye Diagram
  - All Bits, T-bits, nT-bits
- Mask Hits (Waveform Plot)
  - Measuring Mask Hits
- Plot Display and Configuration Options
  - On Selection Panel
  - On Plot Panel

Results Panel and Related Options

- Viewing Results
  - All Acquisitions
  - Current Acquisition
  - Exporting Measurement Data To Ref
- Exporting
  - Measurement Results (Snapshot)
  - Measurement Data (Snapshot)
- Logging
  - Measurement Results
  - Measurement Data
  - Worst Case Waveforms
- Reports
  - Selecting what to include…
- Pass/Fail and Limits Selection and Viewing

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Controlling Eye Diagram - Mean TIE Offset

- Clock Recovery is Crucial
- Most CDR Methods auto-center the Eye diagram
  - Normalized so mean TIE = Zero
  - Clock edge aligned with data edges (overlapping)
- Explicit Clock CDR Method
  - Adds complexity that must be managed
  - Nominal Clock Offset
  - 0ps is a special case = app auto-aligns eye diagram
    - Mean TIE can be non-zero and eye will try to align to clock edges
    - Use 1ps to fix alignment … eye will move as mean TIE increases
    - Set Advanced Nominal Clock Offset to adjust eye position horizontally
    - DDR uses ½ UI as proper offset for Writes, 1ps for Reads
  - Time Trend of Clock and Time Trend of Data can be used to judge offsets >1UI, e.g., a PLL with several cycles of delay…

ANY QUESTIONS?