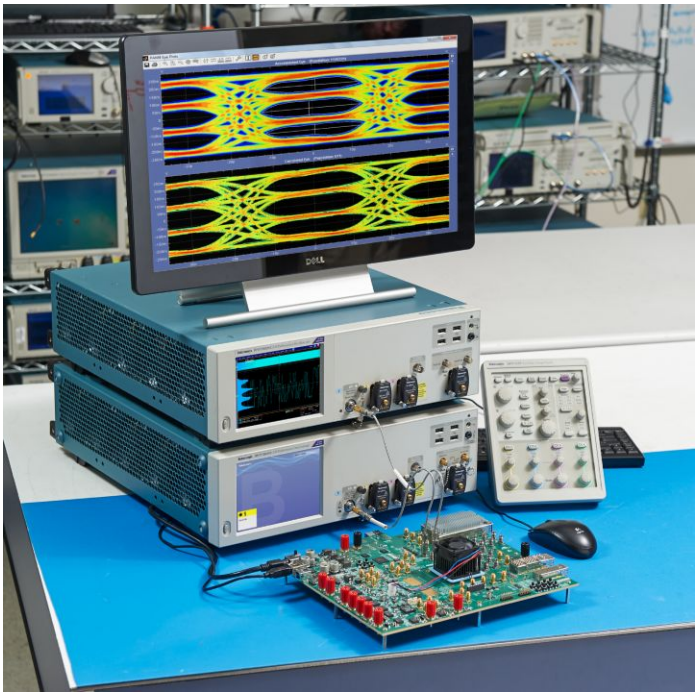
PAM4 Transmitter Analysis



Comprehensive PAM4 Analysis, showing detailed jitter analysis for each eye and global link measurements

Features and benefits

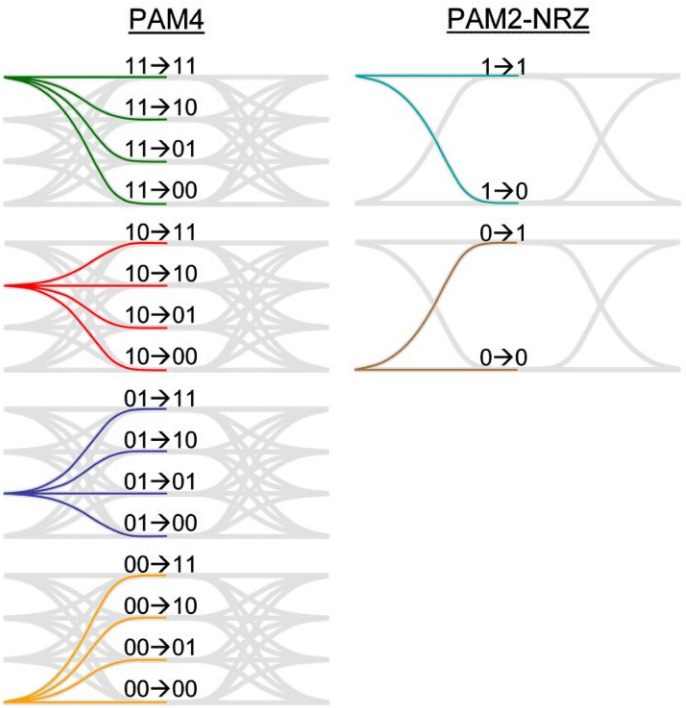
- Single Integrated Application for PAM4 Debug and Validation
  - This application brings together all the capabilities needed for comprehensive PAM4 analysis and debug
  - Dashboard style configuration panel enables quick and easy configuration of all the necessary parameters for PAM4 analysis
- Enhanced Clock Recovery
  - Software clock recovery offers the industry's most robust clock recovery capability even from heavily impaired signals
- Configurable Bessel-Thomson Filter
  - Offers the flexibility to tune bandwidth of the measurement receiver, either manually or automatically, based on detected data rate
- Waveform Filter enables embed or de-embed test fixtures or channel models
- Auto Configuration
  - Auto detect thresholds, symbol rate, pattern type and length, enabling ease of configuration
- Symbol and Bit Error Detector
  - Detect and navigate to individual errors with annotations of clock recovery, eye centers, and expected symbols
  - Accumulate SER and BER over multiple acquisition cycles
- Integrated Receiver Equalization
  - Apply CTLE, FFE and DFE equalization to the acquired waveform to open a closed eye.
  - Model different types of receiver settings to perform what-if analysis
  - Support for standard based equalization presets
- Jitter Measurement and Eye Analysis
  - Full Characterization of the PAM4 eyes to support standard based and debug analysis
  - Isolate the effects of ISI and show the potential for receiver equalization using correlated eye
  - Rise and Fall times for all 12 PAM4 transitions offers the capability to analyze each transition type in PAM4 signal providing greater insight
  - Flexible controls to automatically acquire a desired symbol population across multiple acquisitions
- Noise Analysis and BER Contours
  - Eye width and height analysis per OIF-CEI standards or to custom BER targets
  - Eye diagram annotated to show BER contours and width/height measurement locations
- SNDR Analysis
  - Automates a complex PAM4 transmitter measurement useful for characterization
- Plots and reports
  - Comprehensively interact with plots for measurement visualization and deep analysis
  - HTML report captures all the relevant setup configuration, measurement test results, and plot in single file that is easy to read and share
  - Measurement results across multiple acquisitions can be exported to a consolidated CSV file useful for additional analysis

Applications

- Debug, Analysis, and Characterization of PAM4 signals
- Characterization of OIF-CEI and IEEE based PAM4 standards; such as OIFCEI-VSR-56G-PAM4, 802.3bs, and CDAUI-8.

PAM4 overview

The frequency content of the NRZ signal increases linearly with bit-rate. PAM4 signaling needs half the bandwidth as NRZ for the same data rate. 400G Ethernet standards, both electrical and optical interfaces, adopted PAM4 signaling to support the forecasted growth in the datacenter and network traffic.

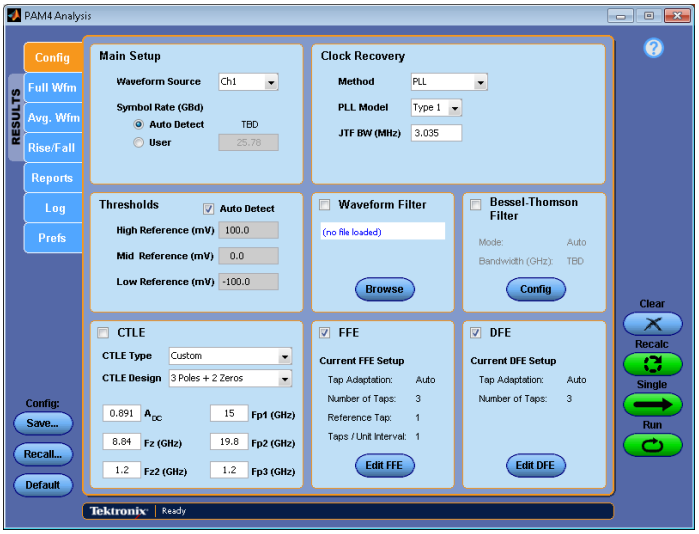


Assumes linear coding for illustration. In practice, gray coding is frequently used.

The 4 levels of PAM4 introduce additional complexity in signaling and place new demands on the test methodology. The PAM4 analysis tool offers several measurement and visualization capabilities aimed at making the task of validating PAM4 designs more efficient.

PAM4 Measurement configuration

The configuration panel is a dashboard within the PAM4 analysis tool that enables you to configure most elements for a PAM4 analysis run. The panel includes; measurement source selection, Clock recovery, Threshold, and Bessel-Thomson filter and Equalization configuration. It also has the ability to embed or de-embed a channel using a waveform filter.



Clock recovery

Configurable PLL (phase-locked loop) clock recovery reliably extracts the symbol clock, even with highly impaired signals, and exports the reconstructed clock waveform to a reference channel where it may be viewed.

Channel Embedding / De-embedding

The waveform filter option offers the ability to embed or de-embed different channel elements. For example:

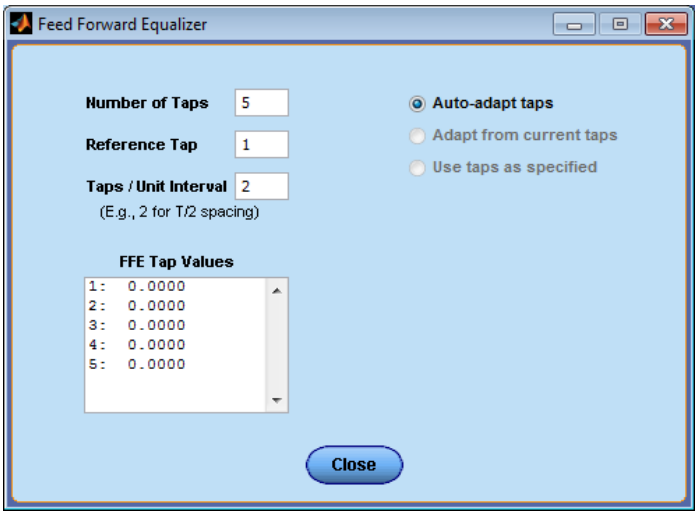
- The effects of a test fixture can be de-embedded to gain visibility of the signal at the transmitter output.
- A channel can be embedded to gain visibility of the signal at the receiver input.

Equalization

It is often necessary to apply receiver equalization to open the eyes before measurements can be performed. In most cases the lack of physical access makes it impossible to verify the receiver circuit behavior and monitor the effects of clock recovery and equalization.

A comprehensive equalizer in the PAM4 analysis tool offers the ability to do the following:

- Apply CTLE either using custom poles and zeros or standards based presets.
- Apply configurable length FFE and / or DFE with auto-adapted tap values.
- Observe the tap values have been chosen.



Auto Configure Capability

The PAM4 analysis application can automatically detect the signal's symbol rate and pattern, and choose the appropriate decision thresholds based on analysis of the eye diagram. This allows quick and error-free set-up, as well as, verifying your signal's key characteristics.

PAM4 Measurements

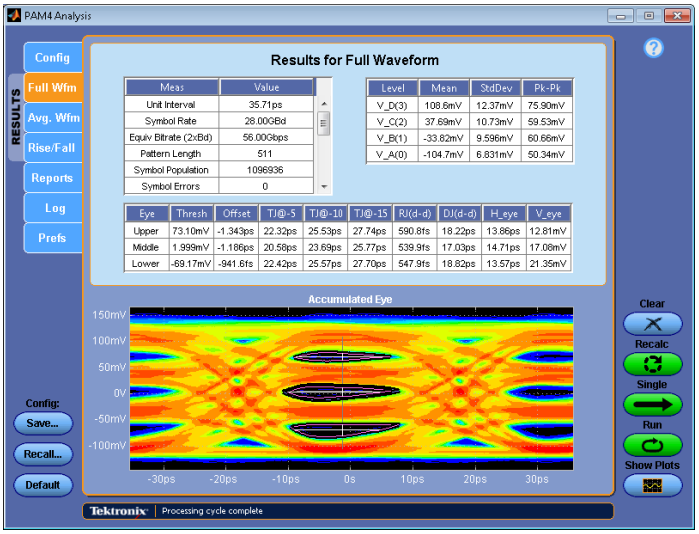
PAM4 analysis package provides a comprehensive set of measurements that offer greater insight into signal characteristics, speeding up validation or characterization of PAM4 designs.

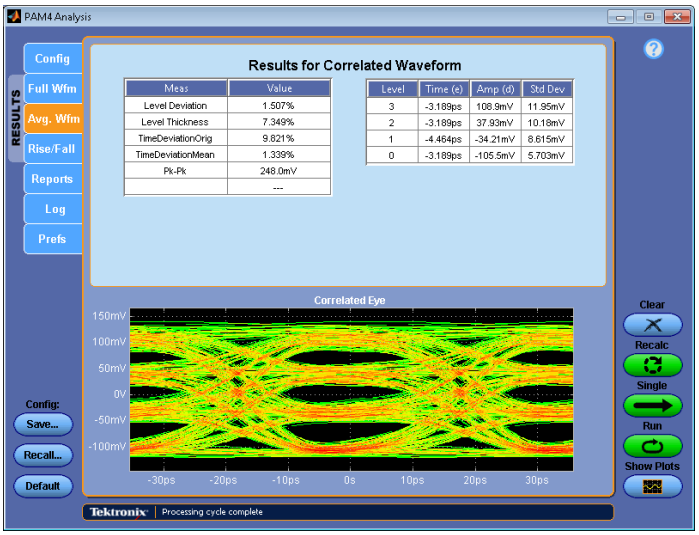
Measurement Sets	
Full waveform measurements	Unit interval, Symbol rate, Equivalent bit rate, Pattern length, Symbol population, Symbol error count, Symbol error ratio, Bit error ratio, Linearity (R_{LM}), EW6, EH6, VEC, SNDR, p_{max}, σ_e, σ_n, UUGJ, UBHPJ, Even-odd jitter
Measurement per level in the PAM4 eye	V_D(3), V_C(2), V_B(1), V_A(0), DJ(dd)
Measurement per eye opening	Threshold, Offset, TJ@BER, RJ(d-d), DJ(d-d), Width, Height, H_upp, H_mid, H_low, V_upp, V_mid, V_low
Measurement for correlated waveform	Level deviation, Level thickness, Time deviation (from origin), Time deviation (from mean), Peak-Peak
Measurement per level in the correlated PAM4 eye	Time at minimum ISI point, Amplitude (d), Standard Deviation at Minimum ISI point
Measurement for Rise and Fall times	Minimum, Maximum, Mean, and Count for all 12 transitions

Full Waveform and Correlated Waveform analysis

A full waveform analysis can be performed by overlaying all the unit intervals on the acquired PAM4 signal. A jitter analysis is done on the individual eyes within the link and the BER eye contours. Both tests can give insight into eye closure at all timing phases and reference levels simultaneously.

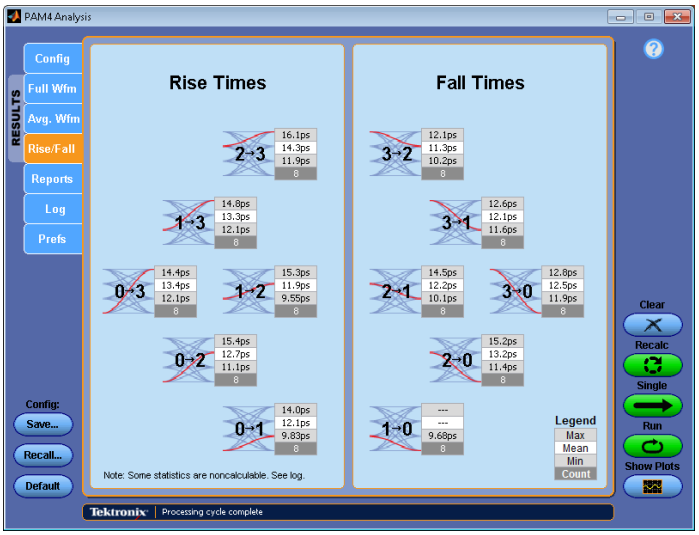
The correlated waveform and eye show how much additional eye opening is theoretically obtainable through equalization. The correlated waveform can be analyzed by tools and techniques similar to those found on Equivalent Time Oscilloscopes. Many performance communications standards assume access to correlated data. The PAM4 Analysis application can effectively model correlated and composite eye diagrams.





Rise and Fall Time analysis

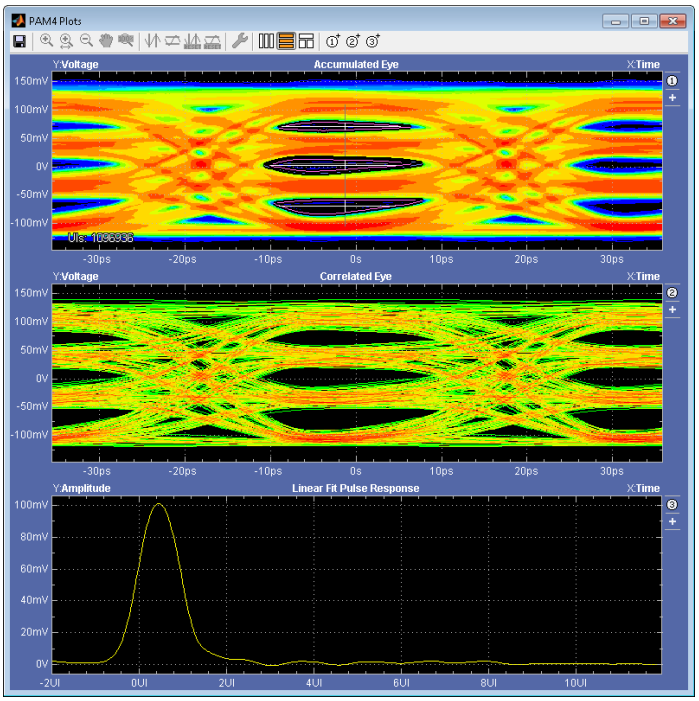
Analysis of the individual transitions rise and fall times helps separate linear impairments (bandwidth, ISI) from nonlinear (slew-rate limiting, clipping). The rise and fall times also support advanced tuning of equalization algorithms. The PAM-4 analysis software provides the max, min, and mean rise and fall time for each of the six transition types within the PAM4 eye.



Visualization

A comprehensive set of plots can be used to visualize measurement data. The plots provide additional insight into the signal characteristics and are useful for debugging.

The plot toolset enables interaction with the plots and can focus in on an area of interest for closer examination and further analysis.



Error Detector

The PAM4 analysis tool comes with a built in error detector that can identify individual symbol errors in the current source waveform. The identified error can be viewed in a dedicated error navigator window.

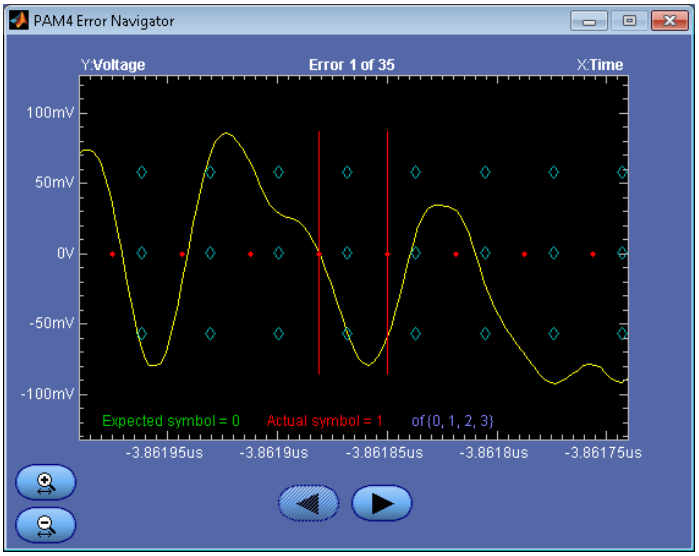
Results for Full Waveform

Meas	Value
Equiv Bitrate (2xBd)	64.00Gbps
Pattern Length	127
Symbol Population	293635
Symbol Errors	35
Symbol Error Ratio	1.1920e-04
Bit Error Ratio	5.9598e-05

Level	Mean	StdDev	Pk-Pk
V_D(3)	87.52mV	5.555mV	46.50mV
V_C(2)	30.04mV	5.538mV	57.35mV
V_B(1)	-28.32mV	6.216mV	56.11mV
V_A(0)	-85.85mV	6.410mV	51.73mV

The error navigator has several capabilities that makes it easy to quickly navigate and zoom into the error location. The additional information for the following detected errors offer help debugging symbol errors on the link:

- Location of recovered clock
- Location of symbol error reference thresholds
- Expected symbol displayed
- Actual symbol displayed



Comprehensive test report and data export

The measurement results can be saved in the form of a test report. The report includes; the configuration of the oscilloscope, application configuration, measurement results, and plots all available in an easy to read or share format.

The measurement results across multiple acquisitions can also be exported to a single CSV file for further analysis.

Full Waveform Results

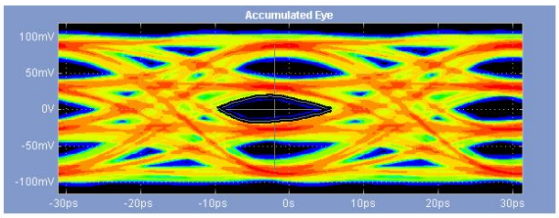
Measurement	Value
Unit Interval	31.25ps
Symbol Rate	32.00GBd
Equiv Bitrate (2xBd)	64.00Gbps
Pattern Length	127
Symbol Population	1253634
Symbol Errors	0
Symbol Error Ratio	0
Bit Error Ratio	0
Linearity (R_{LM})	98.81%
EW6	insufficient data *
EH6	insufficient data *
VEC	insufficient data *
SNDR	23.04dB
P_{max}	86.99mV
σ_s	5.817mV
σ_n	1.937mV
UUGJ	---
UBHPJ	---
Even Odd Jitter	insufficient data *
ER	Disabled
OMA	Disabled
AOP	Disabled

Level	Mean	StdDev	Pk-Pk
V_D(3)	88.05mV	5.808mV	41.51mV
V_C(2)	30.96mV	4.897mV	33.63mV
V_B(1)	-28.11mV	5.783mV	36.13mV
V_A(0)	-85.29mV	5.627mV	37.42mV

Eye	Thresh	Offset	TJ@.5	TJ@.10	TJ@.15	RJ(d-d)	DJ(d-d)	H_eye	V_eye
Upper	59.37mV	821.7fs	21.27ps	24.11ps	25.97ps	464.7fs	18.42ps	n/a *	n/a *
Middle	1.419mV	-687.1fs	19.18ps	22.07ps	23.87ps	449.0fs	16.57ps	n/a *	n/a *
Lower	-56.56mV	-329.6fs	23.10ps	26.05ps	27.92ps	462.7fs	20.39ps	n/a *	n/a *

* requires a population of 4e6 symbols

Full Waveform Eye Diagram



Ordering information

The PAM4 Transmitter analysis software for Tektronix DPO/MSO70000 Win7 Series oscilloscopes

For new DPO/MSO70000 Series oscilloscopes

Product	Option	Description
DPO/MSO70000	PAM4	PAM4 Transmitter Analysis software

For users with existing DPO/DSA/ MSO70000 Series oscilloscopes

Product	Option	Description
DPO-UP	PAM4	PAM4 Transmitter Analysis Software Upgrade
DPOFL PAM4	-	PAM4 Transmitter Analysis software floating license
DPOFT PAM4	-	PAM4 Transmitter Analysis software trial license

Required options

DJA DPOJET Eye and Jitter Analysis.

DJAN DPOJET Noise Analysis.

Recommended options

SDLA64 SDLA Visualizer channel de-embedding, embedding, and equalization.

CE Marking Not Applicable.

Tektronix is registered to ISO 9001 and ISO 14001 by SRI Quality System Registrar.

Product(s) complies with IEEE Standard 488.1-1987, RS-232-C, and with Tektronix Standard Codes and Formats.

Product Area Assessed: The planning, design/development and manufacture of electronic Test and Measurement instruments.