Automotive Ethernet Test Application

Multigigabit Ethernet (Opt. AUTOEN10G), 1000/100BASE-T1 (Opt. BRR), 10BASE-T1S (Opt. AUTON10) Datasheet

Tektronix options AUTOEN10G (MultiGBASE-T1), BRR (100BASE-T1/1000BASE-T1) and AUTOEN10 (10BASE-T1S) comprise the most comprehensive solution for Automotive Ethernet transmitter compliance testing, as well as debug and validation of Automotive Ethernet devices and ECU's, against the IEEE and Open Alliance specifications. The test suite runs on the MSO/DPO70000DX and DPO70000SX, letting you take full advantage of validation and debug capabilities in the oscilloscope, in addition to compliance testing. The integration of Automotive Ethernet is placing greater demands on technology and is placing even greater demands on comprehensive design validation to ensure interoperability between multiple ECU's and reliability in demanding environments. A complete testing solution enables passing strict compliance tests and provides greater confidence in design margins under real-world conditions.

The Tektronix Automotive Ethernet application allows you to select the reference specification, and the test plan depending on the selected specification and currently supports the following data rates and standards:

- 10BASE-T1S as per IEEE 802.3cg and OPEN Alliance TC14.
- 100BASE-T1 as per IEEE 802.3bw and OPEN Alliance TC1.
- 1000BASE-T1 as per IEEE 802.3bp and OPEN Alliance TC12.
- 2.5/5/10GBASE-T1 as per IEEE 802.3ch and OPEN Alliance TC15 [1]

Features and benefits

Test coverage: Tektronix Automotive Ethernet application covers transmitter compliance tests for 100BASE-T1 (IEEE 802.3bw), 1000BASE-T1 (IEEE 802.3bp), MultiGBASE-T1 (IEEE 802.3ch), and 10BASE-T1S (IEEE 802.3cg) standards through a single Automotive Ethernet compliance application. The application uses the TekExpress automation framework and tests as per IEEE and Open Alliance specification for Tektronix DPO70000 SX/DX and MSO's.

Test time: Fully automated with setup wizard, configures all required test parameters to perform compliance testing as per Automotive Ethernet standards. Highly optimized and intuitive user interface for quick test configuration and validation of electrical signals.

Accuracy: The application runs on Tektronix DPO70000 SX/DX series oscilloscopes for accurate and repeatable results.

Pattern matching: Verifies that the correct set of compliance patterns are sent by the transmitter before acquiring signals for compliance analysis.

Reporting: Compiles all test results into a customizable report with pass/fail results for easy analysis and record keeping, as well as margin testing.

Compliance and debug: Provides a toolkit of DPOJET based setups to quickly switch into debug and validation mode when a DUT fails compliance.

Analysis and debug tools: Supporting tools, such as TekExpress user defined Mode, advanced DPOJET jitter analysis (Opt. DJA), PAM4 Eye Diagram Analysis (*Opt. PAM4*) tools help to catch problems before compliance testing, or root-cause the problem in the event of a failure.

Performance verification: The Automotive Ethernet application allows you to run a test multiple times and save or stop acquisitions in the event of an out-of-limit condition. The report shows statistics with pass/fail results for each run to show device performance over multiple runs.

PHY level protocol decode: Opt. SR-AUTOETH1 decodes and displays 100BASE-T1 data in a protocol-aware view. A time-correlated event table view with waveforms allow you to quickly search through decoded data for events of interest.

Comprehensive programmatic interface: Enables automation programs and scripts to call Automotive Ethernet test functions.

Automated Automotive Ethernet compliance application

Physical layer compliance tests have been defined to ensure the interoperability between different designs and hardware vendors. Tektronix Automotive Ethernet compliance testing application provides the most comprehensive solution to serve the need of engineers designing Automotive Ethernet silicon or electronic control units (ECU's), as well as those validating physical layer compliance of Automotive Ethernet as per IEEE or Open Alliance specifications.

	10BASE-T1S	100BASE-T1	1000BASE-T1S	MultiGBASE-T1
IEEE Specification	802.3cg	802.3bw	802.3bp	802.3ch
Data rate	10 Mbps	100 Mbps	1 Gbps	2.5/5/10 Gbps
Symbol rate	12.5 MHz	66.66 MHz	750 MHz	1.4/2.8/5.6 GHz
Line coding	4B/5B, DME	PAM3	PAM3	PAM4
Voltage	1 Vpp	2.2 Vpp	1.3 Vpp	1.3 Vpp
Communication	Half Duplex	Full Duplex	Full Duplex	Full Duplex

Industry defined testing for Automotive Ethernet

The IEEE and Open Alliance provide compliance tests for an Automotive Ethernet PHY or ECU. As per the IEEE and Open Alliance, we have the following compliance requirements for Physical Media Attachment (PMA) transmitter test for an Automotive Ethernet PHY or ECU.

[1] Refer Ordering information section to know more about bandwidth requirements.

Test name	100BASET1 IEEE 802.3 bw	ECU TC8 100/1000BASE-T1	1000BASE -T1 IEEE 802.3 bp	MultiGBASE-T1 IEEE 802.3 ch
Transmitter output Droop	96.5.4.1	OABR_PMA_TX_01	97.5.3.1	149.5.2.1
Transmitter Distortion	96.5.4.2	OABR_PMA_TX_08	97.5.3.2	NA
Transmitter Linearity	NA	NA	NA	149.5.2.2
Transmitter Timing Jitter in Master/ Slave Mode	96.5.4.3	OABR_PMA_TX_02	97.5.3.3	149.5.2.3
Transmitter MDI Jitter	NA	NA	97.5.3.3	NA
Tx MDI Random Jitter (Master)	NA	NA	NA	149.5.2.3.1
Tx MDI Deterministic Jitter (Master)	NA	NA	NA	149.5.2.3.2
Transmitter Power Spectral Density (PSD)	96.5.4.4	OABR_PMA_TX_04	97.5.3.4	149.5.2.4
Transmit Clock Frequency	96.5.6	OABR_PMA_TX_03	97.5.3.6	149.5.2.6
Transmitter Peak Differential Output	96.5.4.5	NA	97.5.3.5	149.5.2.5
MDI Return Loss	96.8.2.1	OABR_PMA_TX_05	97.7.2.1	149.8.2.1
MDI Mode Conversion	NA	OABR_PMA_TX_06	NA	NA
Common Mode Emission	NA	Only 100BASET1	NA	NA

Each test requires the engineer to set the required test mode, acquire waveforms with the correct instrument settings, and analyze the results per the standard. Manually capturing and analyzing them is tedious, time consuming, and subject to errors.

The TekExpress Automotive Ethernet compliance application allows you to automatically execute physical layer electrical tests for transmitter compliance using IEEE and/or Open Alliance (OABR) specifications. The Tektronix Opt. BRR and AUTOEN10G applications combine to form a TekExpressTM compliance automation solution for 100BASE-T1, 1000BASE-T1 and MultiGBASE-T1 Automotive Ethernet with a single user interface. The TekExpress Automotive Ethernet application is configured by following a step-bystep process. The application sets up the oscilloscope and automates testing, guiding you to accurate and repeatable results.

MultiGBASE-T1 PMA transmitter compliance measurements

MultiGBASE-T1 is specified in IEEE 802.3ch, an extension to BASE-T1 PHYs at speeds in excess of 1000 Mb/s, including 2.5GBASE-T1, 5GBASE-T1, and 10GBASE-T1. The physical layer operates over a single pair of shielded cable in full-duplex mode with four level pulse amplitude modulation (PAM4).

Table 1: MultiGBASE-T1 PMA transmitter measurements

Test specification	Test mode	Pattern type	Instrument
Tx Output Droop	6		Oscilloscope
Tx Linearity	4	PAM4	Oscilloscope
Tx Timing Jitter (Master and Slave)	1	Clock	Oscilloscope
Tx MDI Random Jitter (Master Mode)	2	Square	Oscilloscope
Tx MDI Deterministic Jitter (Master Mode)	2	JP03A	Oscilloscope
Even Odd Jitter (EOJ)	2	JP03B	Oscilloscope
Tx Power Spectral Density and Power level	5	PAM4	Oscilloscope
Tx Clock Frequency	1	Clock	Oscilloscope
Tx Peak Differential Output	5	PAM4	Oscilloscope
MDI Return Loss	Slave		VNA

Table 2: 1000BASE-T1 PMA transmitter measurements

Test specification	Test mode	Pattern type	Instrument
Tx Output Droop	6		Oscilloscope
Tx Distortion	4	PAM3	Oscilloscope
Tx Timing Jitter (Master and Slave)	1	Clock	Oscilloscope
Tx MDI Jitter	2	Clock	Oscilloscope
Tx Power Spectral Density and Power level	5	PAM3	Oscilloscope
Tx Clock Frequency	1	Clock	Oscilloscope
Tx Peak Differential Output	5	PAM3	Oscilloscope
MDI Return Loss	Slave		Vector Network Analyzer or Oscilloscope + AWG
MDI Mode Conversion	Slave		VNA

Table 3: 100BASE-T1 PMA transmitter measurements

Test specification	Test mode	Pattern type	Instrument
Tx Output Droop	6		Oscilloscope
Tx Distortion	4	PAM4	Oscilloscope
Tx Timing Jitter (Master and Slave)	1	Clock	Oscilloscope
Tx Power Spectral Density and Power level	5	PAM3	Oscilloscope
Tx Clock Frequency	2	Clock	Oscilloscope
Tx Peak Differential Output	5	PAM3	Oscilloscope
MDI Return Loss	Slave		VNA
MDI Mode Conversion	Slave		VNA
MDI Common Mode Emission	5	PAM3	Oscilloscope

Table 4: 10BASE-T1S PMA transmitter measurements

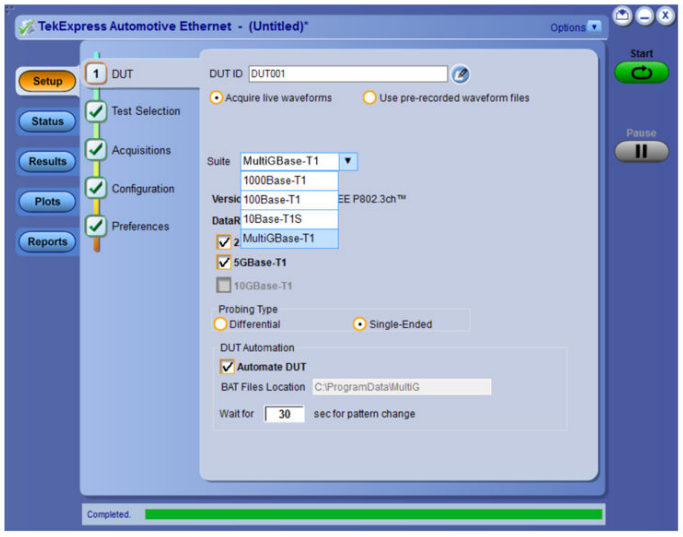
Test specification	Test mode	Instrument
Tx Output Droop	2	Oscilloscope
Tx Timing Jitter	1	Oscilloscope
Tx Power Spectral Density and Power level	3	Oscilloscope
Tx Peak Differential Output	1	Oscilloscope
MDI Return Loss	Slave	Oscilloscope + AFG

The TekExpress Automotive Ethernet automated testing application

The Tektronix Automotive Ethernet application offers exceptional ease of use with the TekExpress Automation platform. Testing follows a logical workflow for quick, easy test setups, changes and review of test results. Valid testing requires proper cabling, probes, and connections between fixtures, instruments, and the device under test (DUT). The TekExpress Automotive Ethernet application provides setup instructions for each test, with images and reference illustrations showing correct configurations. It generates a comprehensive, date-stamped test report with pass/fail results, waveforms, and data plots.

Accurate, repeatable compliance tests follow a 5-step workflow.

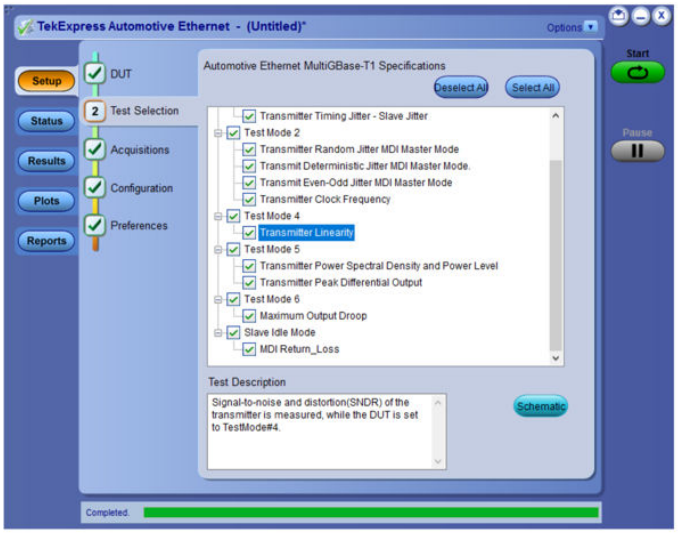
Step 1: Selection of test suite



Selection of test suite in the DUT panel

Test selections includes Automotive Ethernet 100BASE-T1, 1000BASE-T1, and MultiGBASE-T1. You can select different speed gears for MultiGBASE-T1. The test selection, test limits, and configuration will be selected based on the test suite chosen. You can test using live oscilloscope waveforms or previously recorded waveforms or sessions.

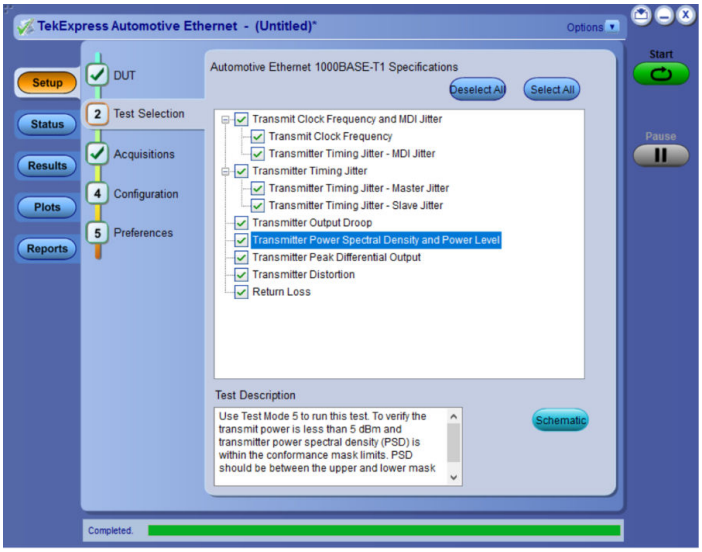
Step 2: Test selection



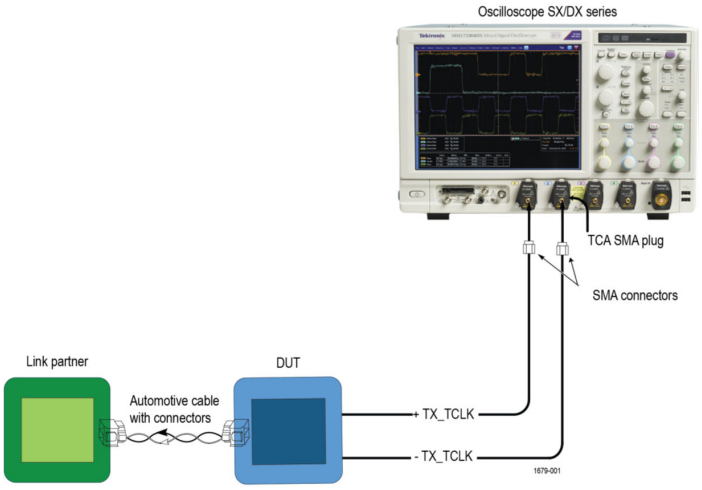
Multigigabit Ethernet test selection

Based on the test suite selection in Step 1, the TekExpress Automotive Ethernet application allows you to select one or multiple tests from the test tree for the respective test suite.

A schematic views and descriptions guide you through connections, along with test information and golden waveforms. If you select multiple tests, the application will provide prompts to set the correct DUT test mode and make the appropriate connections.



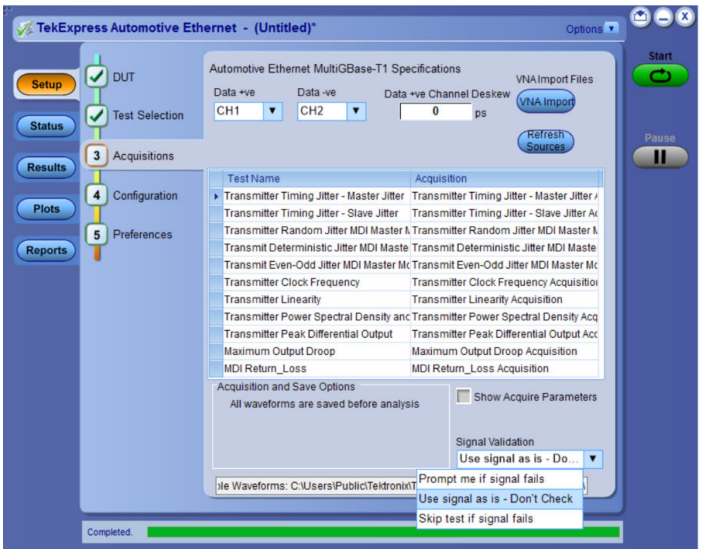
Automotive Ethernet 1000BASE-T1 Test selection



Note: For best resuts, connect the oscilloscope, DUT and test fixtures to a common ground.

Automotive Ethernet connection diagram

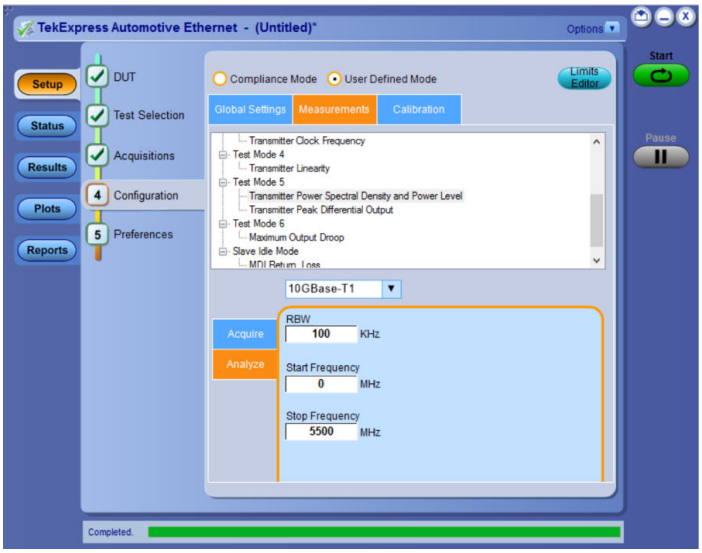
Step 3: Signal validation



Signal acquisition and validation

It is important to validate the signal parameters before performing a compliance test. The TekExpress application checks for the correct test mode waveform before running any test. This ensures that the proper test connections are in place and that the DUT is sending the appropriate test pattern.

Step 4: Configuration of User defined and Compliance Mode

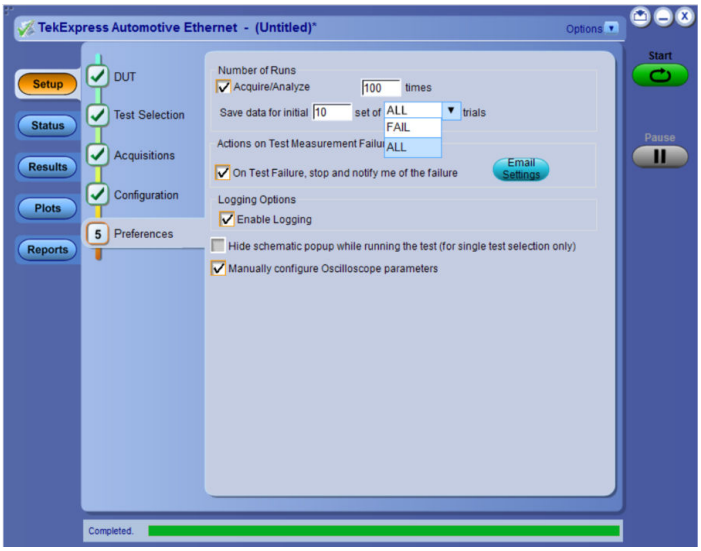


User defined configuration for PSD test

The TekExpress Automotive Ethernet application allows you to configure the test in compliance mode or user defined mode. In compliance mode, the application configures the oscilloscope per the test procedure defined in the test specifications from the applicable standard. The DUT is tested against limits defined by the standard.

In user defined mode, you can change the test parameters such as record length, sample rate, etc., as well as test limits. User-defined Mode allows you to test your device beyond compliance.

Step 5: Preferences



Multi-run configuration for statistical analysis

The TekExpress application allows you to run multiple consecutive tests for statistical analysis. You can save the waveforms from failed tests for debugging.

Pass/Fail report:

Detailed pass/fail report of MultiGBASE-T1

Creating compliance test documentation is quick and easy in the TekExpress application with a summary report in MHL or PDF formats. The TekExpress application generates a report after the test execution is complete, and includes pass/fail status to quickly analyze the test results. The report also includes test configuration details, waveform plots, oscilloscope displays, margin analysis, and statistical analysis to provide insights into your design.

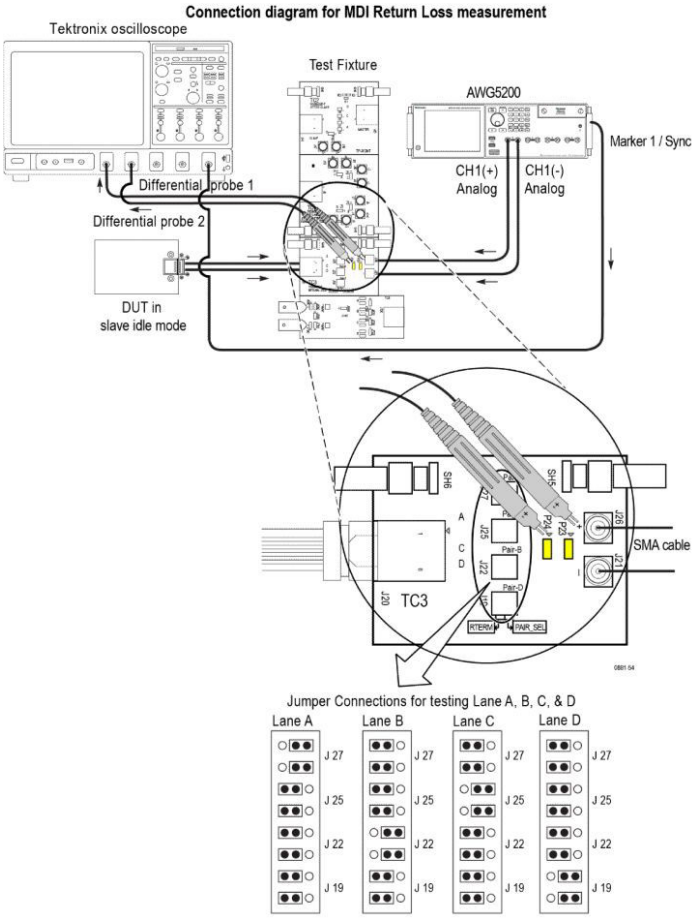
Single instrument for time domain and frequency domain measurements

Automotive Ethernet compliance testing includes time domain measurements like jitter, droop, clock frequency and peak differential output. It also includes frequency domain measurements such as power spectral density and return loss. The Tektronix Automotive Ethernet application allows you to perform all of these measurements using an oscilloscope, eliminating the need to connect a spectrum analyzer or vector network analyzer.

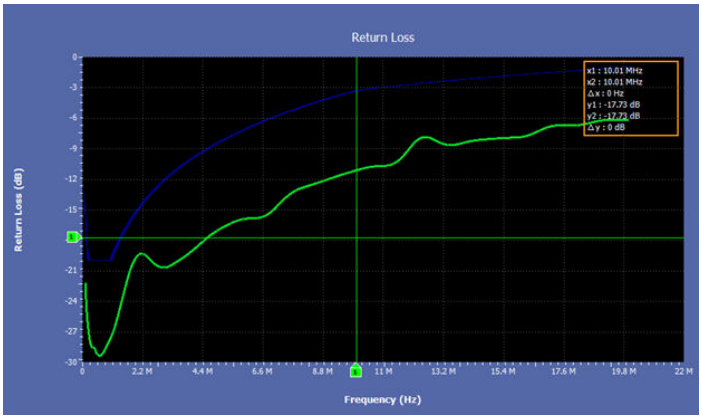
Return loss measurement

The MDI return loss measurement determines the impedance mismatch from the differential impedance specification of 100 Ω, which will affect hardware interoperability. Return loss is a frequency domain

measurement, but the Automotive Ethernet application can perform this test with an oscilloscope and function generator using a patented measurement approach. Return loss using this method is available for 10BASE-T1S, 100BASE-T1, and 1000BASE-T1.



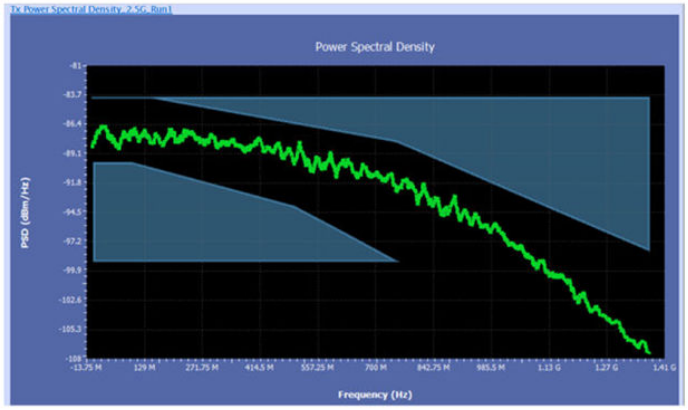
Tektronix patented return loss measurement using oscilloscope and AWG for 100/1000BASE-T1



Return loss plot generated using oscilloscope and AWG method

Power spectral density

The power spectral density of a test signal for the selected standard is computed using oscilloscope math functions. Post processing is done on the signal to arrive at the PSD. The computed PSD is then compared with the specification by using lower and upper masks to arrive at the final result.



Power sprectral density plot

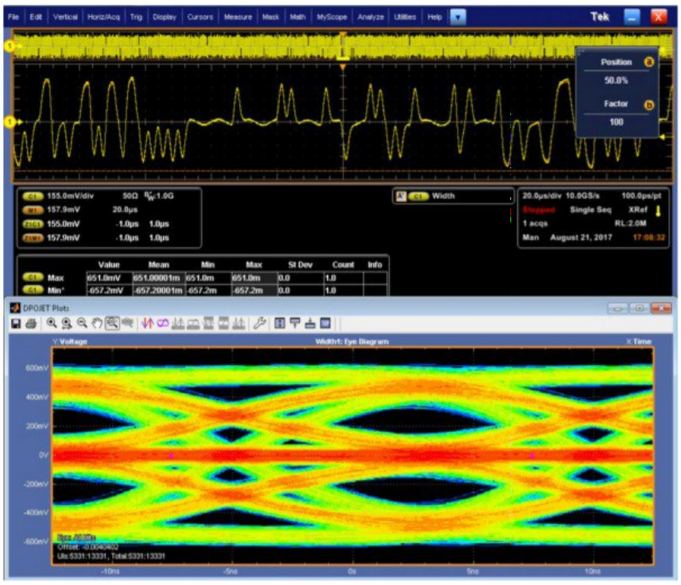
Analysis and debug beyond compliance

If a DUT fails any portion of the compliance test, powerful debugging and analysis tools such as DPOJET jitter analysis, PAM4 analysis, and protocol decoding are available to determine root cause and examine system-level performance.

DPOJET Jitter Analysis measurements (Opt. DJA)

The new jitter measurements introduced with MultiGBASE-T1 Ethernet provide separate limits for Deterministic Jitter (DJ), Even Odd Jitter (EOJ) and Random jitter (Rj). The DPOJET jitter analysis tool provides additional analysis capabilities like crosstalk and power noise separation to help find the root cause of failures.

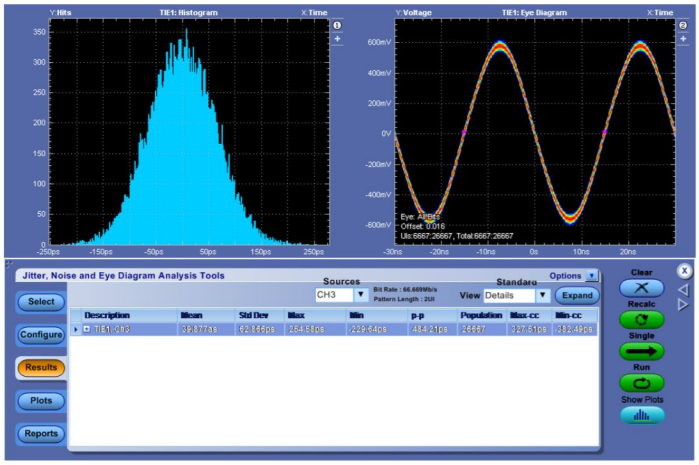
Jitter tests quantify the timing variations of the edges of the signal, using specified test patterns. These jitter measurements include the contributions from duty cycle distortion and baseline wander. Jitter is determined by accumulating waveforms and measuring the width of the accumulated points at the eye crossing. The peak-to-peak jitter is inferred from minimum and maximum values in the tails of the histogram.



PAM3 Eye diagram using DPOJET

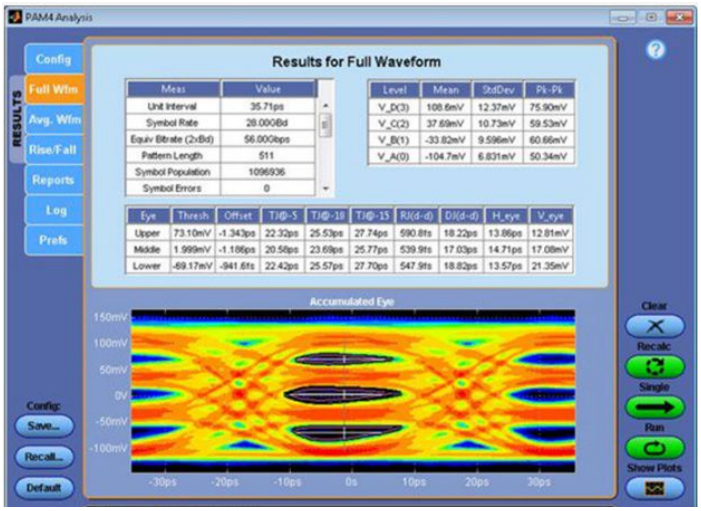
Apart from jitter measurements for MultiGBASE-T1, DPOJET allows you to perform analysis for following measurements:

- Clock frequency and transmitter amplitude with histogram and trend analysis
- Positive and negative droop measurements
- Full characterization of jitter performance including TIE and histogram profiles.



Jitter measurement and analysis using DPOJET

PAM4 Analysis (Option PAM4)



PAM4 analysis

Automotive MultiGBASE-T1 uses four-level Pulse Amplitude Modulation (PAM4) for physical layer transmission since PAM4 signaling needs half the bandwidth as NRZ for the same data rate. However 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 to make validating PAM4 designs significantly more efficient.

PAM4 Analysis

- Enhanced software clock recovery offers the industry's most robust clock recovery capability even from heavily impaired signals.
- 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.
- 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.

PAM4 Measurements

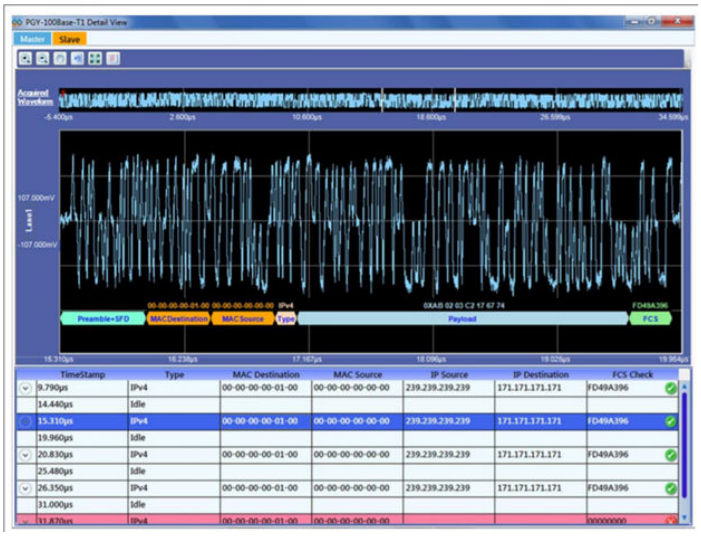
- Jitter measurement and eye analysis: Full Characterization of the PAM4 eyes to support standard based and debug analysis.
- Rise and fall times for all 12 PAM4 transitions offer the capability to analyze each transition type in the PAM4 signal.
- Symbol and bit error detector: Accumulate SER and BER over multiple acquisition cycles.

Plots and reports

- Comprehensive plots enable in-depth 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 for easy multi-run analysis.

Automotive Ethernet decoder for 100BASE-T1 (Opt. SR-AUTOETH1)



100BASE-T1 Protocol decode solution

Decode and display Automotive Ethernet data in a protocol-aware view with the characters and names that are familiar from the standard such as the ordered sets: SOF, Electrical Idle, and EOF.

You can now feed the output of directional coupler to Tektronix oscilloscope for time domain view. SR-AUTOETH1 100BASE-T1 protocol decode software runs on DPO70000SX and MSO/DPO70000 Series oscilloscopes and easily decodes PAM3-encoded 100BASET1 signal. This enables engineers to quickly understand the protocol activity between the ECUs. A time-correlated event table view with waveform allows for quickly searching through events of interest simultaneously.

Key feautures

- Decodes PAM3 encoded 100BASE-T1 signals.
- Decodes Send_N mode packets without any training sequence.
- Validate FCS and reports error packets in red.
- Display the time stamp, packet type, IP source and destination address, decoding of the payload.
- Detail view correlates the decoded packets with waveform using a bus diagram.
- Separately displays Master and Slave packets.
- Export the decoded data in CSV or TXT file format.
- Report generation.

Ordering information

Standard	Compliance test	Instrument	Model number
Multigigabit Ethernet	Droop, Linearity, Dj and Rj Jitter, Power Spectral Density, Clock frequency, Peak Differential output	Oscilloscope with bandwidth • ≥ 4 GHz bandwidth for 2.5Gbps • ≥ 8 GHz bandwidth for 5Gbps • ≥ 13 GHz bandwidth for 10Gbps	DPO70000 SX/DX series, MSO6B series
	MDI Return Loss	Vector Network Analyzer with bandwidth ≥ 4 GHz	8.5 GHz ShockLine MS46522B 2-port Anritsu VNA
1000BASE-T1	Droop, Jitter, Power Spectral Density, Clock frequency, Peak Differential output	Oscilloscope with bandwidth ≥ 2 GHz	DPO70000 C/SX/DX series, MSO5/6B series
	Distortion Test	2 channel Function Generators with bandwidth ≥ 125 MHz	AFG31000 series or AWG5200
	MDI Return Loss	AWG or Vector Network Analyzer	8.5 GHz ShockLine MS46522B 2-port Anritsu VNA
	MDI Mode conversion	Vector Network Analyzer	8.5 GHz ShockLine MS46522B 2-port Anritsu VNA
100BASE-T1	Droop, Jitter, Power Spectral Density, Clock frequency, Peak Differential output, Common mode emission	Oscilloscope with bandwidth ≥ 1 GHz	DPO70000 C/SX/DX series, MSO5/6B series
	Distortion Test	2 channel Function Generators with bandwidth ≥ 25 MHz	AFG31000 series
	MDI Return loss	AFG(125 MHz) or Vector Network Analyzer	8.5 GHz ShockLine MS46522B 2-port Anritsu VNA
	MDI Mode conversion	Vector Network Analyzer	8.5 GHz ShockLine MS46522B 2-port Anritsu VNA
10BASE-T1S	Droop, Jitter, Power Spectral Density, Clock frequency, Peak Differential output	Oscilloscope with bandwidth ≥ 350 MHz	DPO70000 SX/DX series, MSO5/6B series
	MDI Return loss	Arbitrary Function Generators	AFG31000 Series

Software option

Standard	Compliance test	Option	Description
MultiGBASE-T1	802.3ch Transmitter Compliance	AUTOEN10G	TekExpress Automotive Ethernet -MultiGBASE-T1 Compliance Solution(Requires Opt. DJA)
		DPO-UP AUTOEN10G	TekExpress Automotive Ethernet -MultiGBASE-T1 Compliance Solution(Requires Opt. DJA); Upgrade
		DPOFL-AUTOEN10G	TekExpress Automotive Ethernet -MultiGBASE-T1 Compliance Solution(Requires Opt. DJA); Floating

Table continued…

Standard	Compliance test	Option	Description
100/1000BASE-T1	IEEE and Open Alliance PMATransmitter compliance	BRR	TekExpress Automotive Ethernet Compliance
		DPO-UP BRR	TekExpress Automotive Ethernet Compliance; Upgrade
		DPOFL-BRR	TekExpress Automotive Ethernet Compliance; Floating
100BASE-T1	Protocol decode	SR-AUTOETH1	Automotive Ethernet 100BASE-T1 Protocol decode
10BASE-T1S	IEEE and Open Alliance PMA Transmitter Compliance	AUTOEN10	TekExpress Automotive Ethernet - 10BASE-T1S Compliance Solution
		DPO-UP AUTOEN10	TekExpress Automotive Ethernet - 10BASE-T1S Compliance Solution
		DPOFL-AUTOEN10	TekExpress Automotive Ethernet - 10BASE-T1S Compliance Solution; Floating

Pre-requisite software

Standard	Option	Description
MultiGBASE-T1	DJA	Advance Jitter Analysis (Order preinstalled on a new oscilloscope)
	5XL	Extended record length - 62.5 M/Ch (required only with DPO70000 DX model)

Optional software

Standard	Option	Description
MultiGBASE-T1	PAM4	PAM4 Transmitter Analysis
Low Speed Protocol decode	SR-AUTO	CAN, LIN, FlexRay serial bus trigger and decode

MDI Return Loss with AWG/AFG method

Standard	Model number	Description
1000BASE-T1	AWG5202 with opt 250, 2 HV	Tektronix AWG5200 with high amplitude DC coupled with output option
	TDP3500 (2 nos)	3.5 GHz Differential Probe with TekVPI™ Probe Interface s (require TCA-VPI50 adapter)
100BASE-T1	AFG31152	1 µHz to 150 MHz sine wave, 2-channel arbitrary function generator
	TDP1500 (2 nos)	1.5 GHz Differential Probe with TekVPI™ Probe Interface s (require TCA-VPI50 adapter)

Probe

Standard	Model number	Description
MultiGBASE-T1 (Optional)	TDP3500	3.5 GHz Differential Probe with TekVPI™ Probe Interfaces (require TCA-VPI50 adapter), for clock measurement
1000BASE-T1	TDP3500	3.5 GHz Differential Probe with TekVPI™ Probe Interfaces (require TCA-VPI50 adapter)
100BASE-T1	TDP1500	1.5 GHz Differential Probe with TekVPI™ Probe Interfaces (require TCA-VPI50 adapter)

Accessory

Accessory	Part number	Use case
Multigigabit Ethernet Fixture	PCB S3401 SB 396373 [2]	Compliance measurement
100/1000BASE-T1 Fixture100/1000BASE-T1 Fixture	TF-XGBT	Compliance measurement
	02K3E6 K00S3 387390 [2] 02K3E6 S00S3 387391 [2] 02S3E6 S00S3 387392 [2] 02S3E6 K00S3 387393 [2]	Mode conversion and Return loss fixture with Rosenberger connector type
100BASE-T1 Protocol decode fixture	DCDP for H-MTD	Protocol decode directional coupler
Clock divider unit	TF-BRR-CFD	Distortion test
Cable [2]	SMA(f) to SMA(m) phase stable cables and N(m) to SMA(m) adapters (2 nos)	Return Loss and MDI Mode conversion
Cal kit for Anritsu [2]	TOSLKF50A-20 calibration kit	MDI Return and Mode conversion loss
Power splitter [2]	Mini circuit Z99SC-621	Common mode emission test

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.

[2] 3rd Party items

CALPLUS
Die Kompetenz in der Messtechnik

CalPlus GmbH
Zentrale Berlin
Heerstraße 32 • 14052 Berlin
Tel.: 030 214982-0 • Fax: 030 214982-50
office@calplus.de • www.calplus.de

CalPlus GmbH
Niederlassung ScopeShop
Normannenweg 30 • 20537 Hamburg
Tel.: 040 3039595-0 • Fax: 040 3039595-50
scopeshop@calplus.de • www.calplus.de

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www.tek.com

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