直播大讲堂—深入浅出聊以太网物理层测试

致工程师：This is how legends are born!

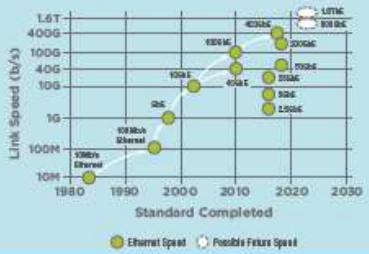
主讲人：刘剑——**泰克高级应用工程师**

2021/3/1

ETHERNET ROADMAP

THE PAST, PRESENT AND FUTURE OF ETHERNET

ETHERNET SPEEDS



NEXT ETHERNET ERA

ethernet alliance

www.ethernetalliance.org

INTEROPERABILITY AND CERTIFICATION

The Ethernet Alliance is committed to leading the charge to instilling industry confidence in Ethernet standards through its multivendor interoperability demonstrations and plugfests. Our PoE Certification Program takes this mission to the next level!

Our industry-defined PoE Certification Test Plan is based on the Ethernet PoE standard, and products passing this test will be granted the Ethernet Alliance PoE Certification Logo. This logo will provide instant recognition for products that are based on the IEEE 802.3 PoE standard, and provide confidence in the multi-vendor interoperability of those products bearing it. The logos will also provide clear guidance on which devices will work with each other.

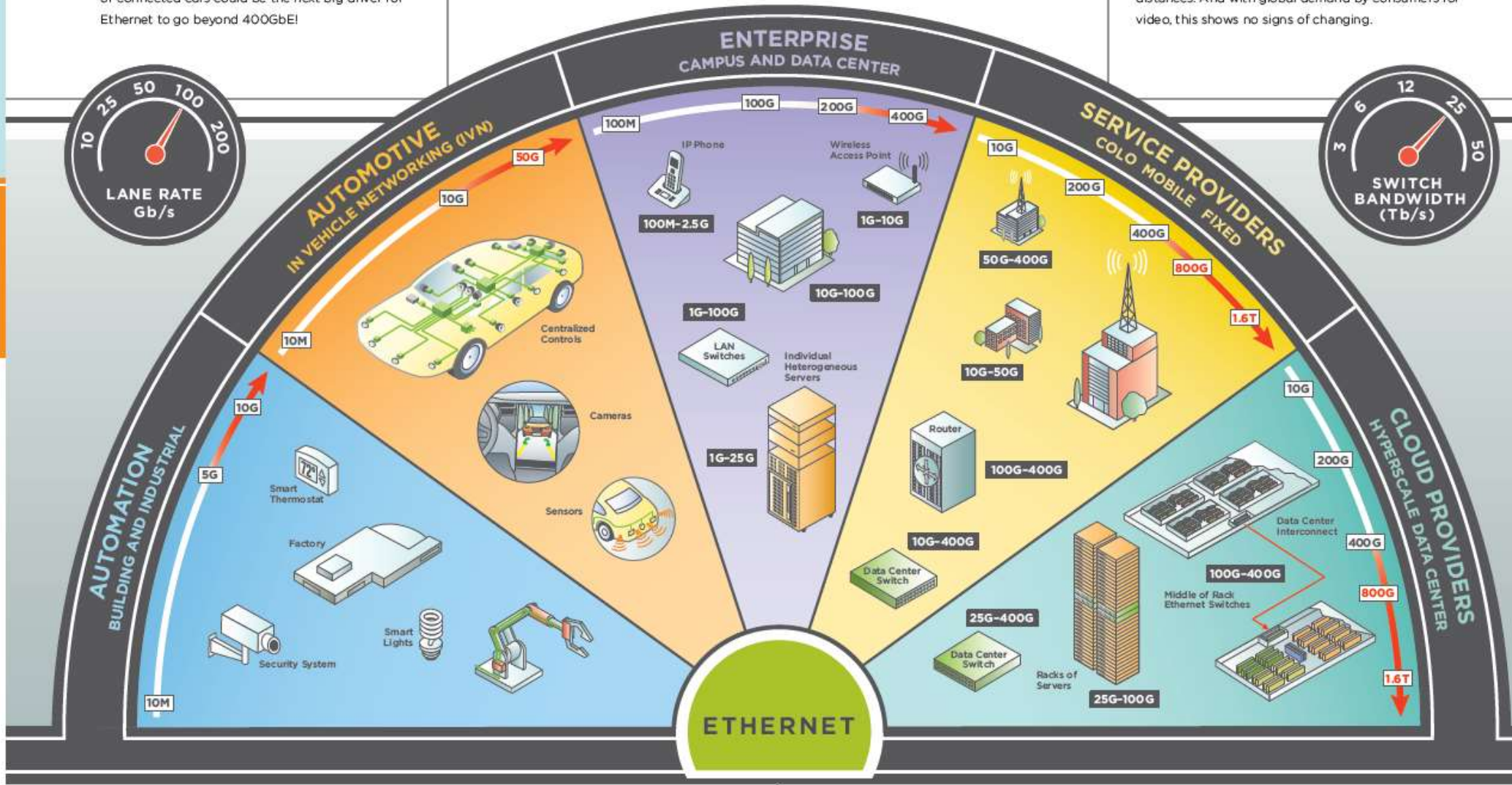
The first generation of the program certifies Type 1 and Type 2 products that use 2-Pair of wires. The second generation of the program tackles the IEEE802.3bt standard. This table explains the capabilities of the Types.

PoE Types and Classes	2-Pair PoE – Type 2 / 2-Pair PoE – Type 1					4-Pair PoE in Standardization			
Class	0	1	2	3	4	5	6	7	8
PSE Power (W)	15.4	4	7	15.4	30	45	60	75	90

AUTOMOTIVE Ethernet is one of Ethernet's latest success stories. Forecasts predict up to 500 million ports of Ethernet will ship in over 100M vehicles by 2021. Ethernet links within cars provide data and power to reduce the cost and weight in vehicles while providing economies of scale and interoperability. The bandwidth demand of connected cars could be the next big driver for Ethernet to go beyond 400GbE!

ENTERPRISE and Campus applications drive the bulk of Ethernet port shipments with hundreds of millions of ports shipping per year. Ethernet's roots are in enterprise local area networks (LANs) where the entire Ethernet family, including the BASE-T products, can be found. LANs are rich in copper where over 70 Billion meters of cable have been deployed over the past 15 years. Enterprise data centers are very cost sensitive and most servers deploy GbE and 10GbE, and are expected to transition to 25GbE.

SERVICE PROVIDERS have driven higher speed Ethernet solutions for decades. Router connections, EPON, client side optics for optical transport network (OTN) equipment, and wired and wireless backhaul. In particular, the 5G mobile deployment is driving dramatic increases in both fronthaul and backhaul applications, and continues to push Ethernet to higher rates and longer distances. And with global demand by consumers for video, this shows no signs of changing.



AUTOMATION, BUILDING, AND INDUSTRIAL applications highlight the need for lower speed Ethernet solutions in harsh environments. Today this space is

CLOUD PROVIDERS were the first to adopt 10GbE servers on a large scale in 2010 for hyperscale data centers. With voracious appetites for applications like AI and Machine Learning, hyperscale

LATEST INTERFACES AND NOMENCLATURE

	Backplane	Twinax Cable	Twisted Pair (1 Pair)	Twisted Pair (4 Pair)	MMF	500m PSM4	2km SMF	10km SMF	20km SMF	40km SMF	80km SMF	Electrical Interface
10BASE-	T1S		T1S/T1L									
100BASE-			T1									
1000BASE-			T1	T								
2.5GBASE-	KX		T1	T								
5GBASE-	KR		T1	T								
10GBASE-			T1	T				BIDI Access	BIDI Access	BIDI Access		
25GBASE-	KR	CR/CR-S		T	SR			LR/ EPON/ BIDI Access	EPON/ BIDI Access	ER/ BIDI Access		25GAUI
40GBASE-	KR4	CR4		T	SR4/eSR4	PSM4	FR	LR4				XLAUI XLPPI
50GBASE-	KR	CR			SR		FR	EPON/ BIDI Access LxR	EPON/ BIDI Access	BIDI Access ER		LAUI-2/50GAUI-2 50GAUI-1
100GBASE-	KR4 KR2 KR1	CR10 CR4 CR2 CR1			SR10 SR4 SR2 SR1	PSM4 DR	10X10-2km CWDM4/ FR1 100G-FR	10X10-10km LR4/ 4WDM-10 LR1 100G-LR	4WDM-20	ER4/ 4WDM-40	ZR	CAUI-10 CPPI CAUI-4/100GAUI-4 100GAUI-2 100GAUI-1
200GBASE-	KR4 KR2	CR4 CR2			SR4 SR2	DR4	FR4	LR4		ER4		200GAUI-4 200GAUI-2
400GBASE-	KR4	CR4			SR16 SR8/SR4.2 SR4	DR4	FR8 FR4 400G-FR4	LR8 LR4-6 400G-LR4-10		ER8	ZR	400GAUI-16 400GAUI-8 400GAUI-4

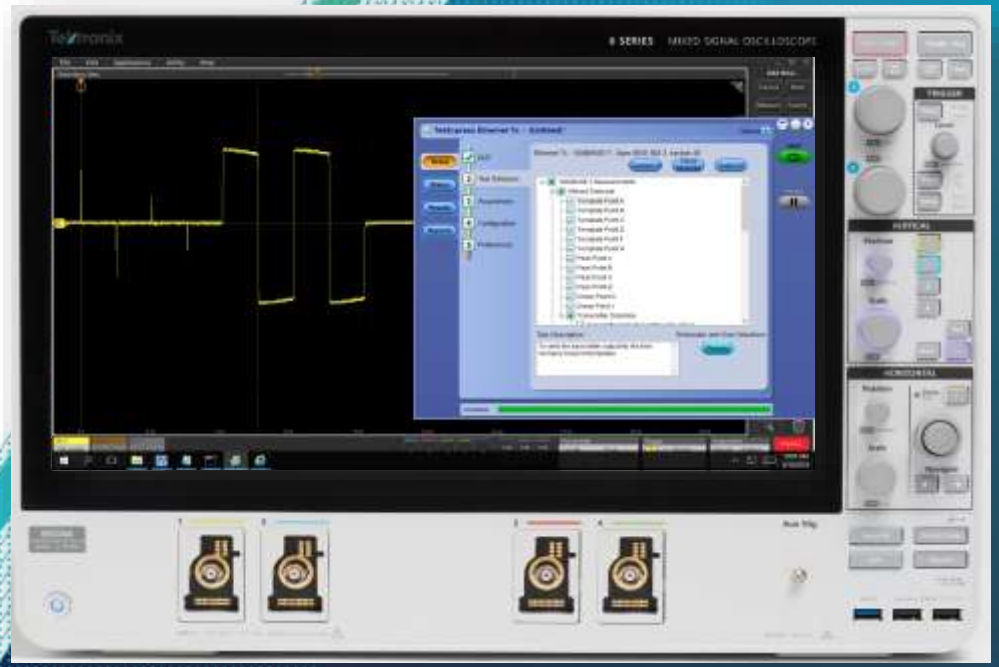
Gray Text = IEEE Standard Red Text = In Standardization Green Text = In Study Group

Blue Text = Non-IEEE standard but complies to IEEE electrical interfaces

- 802.3标准第一次颁布是在1985年（IEEE Std 802.3-1985），从初始颁布以来，很多项目一直为标准添加功能或者提供维护更新。每一个802.3的项目或者补充增改都会添加后缀，比如（IEEE Std 802.3ba™-2010）
- IEEE Std 802.3的主要版本在市场上以他们的项目号来鉴别，比如802.3u™增加了100Mbps的功能，802.3z添加了1000Mbps的功能，802.3ae添加了10Gbps的功能，802.3ah™定义了接入网以太网，802.3ba添加了40Gbps以及100Gbps的功能等等，幸运的是，这些主要的版本都被包含进IEEE Std 802.3-2015，而不再单独维护。

Tektronix

1000/100/10 BASE-T Ethernet



Agenda

- 1000 BASE-T
- 100 BASE-T
- 10 BASE-T
- Return Loss
- TekExpress Ethernet Software
- Summary

1000 BASE-T
- Test Modes
- Key Measurements

1000BASE-T OSI model

REFER TO 802.3 CLAUSE 40

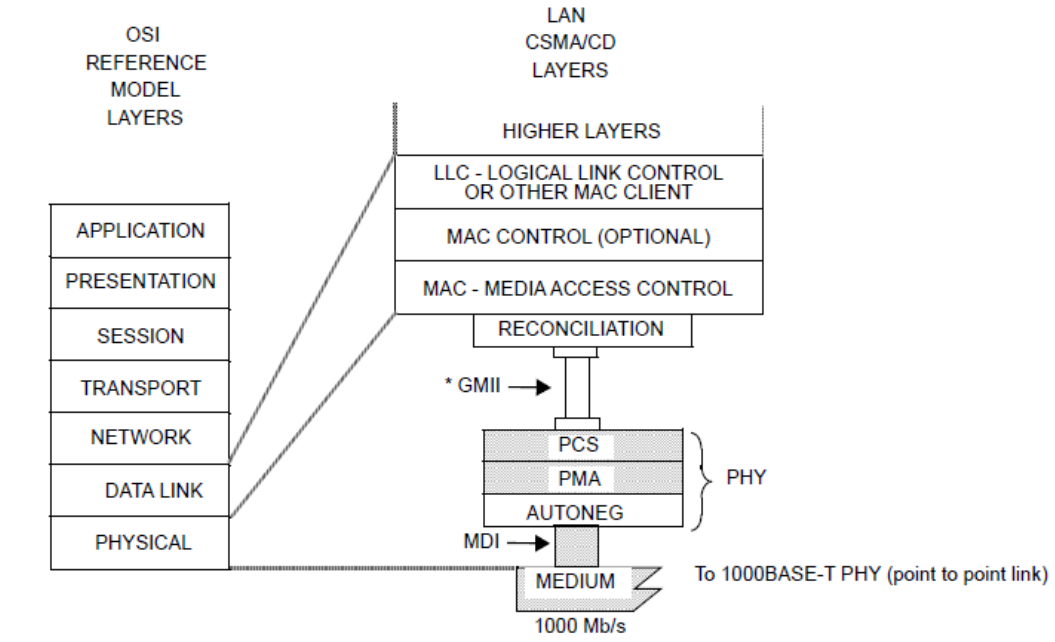
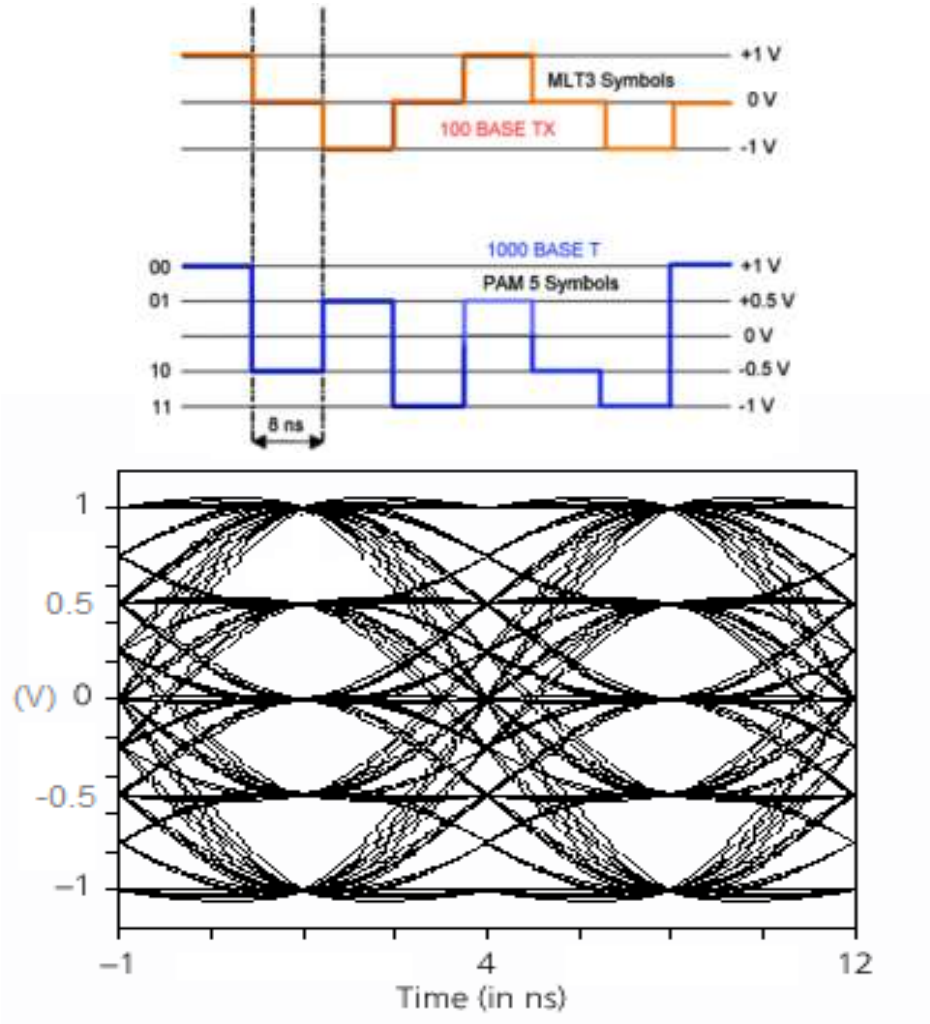


Figure 40–1—Type 1000BASE-T PHY relationship to the ISO Open Systems Interconnection (OSI) Reference Model and the IEEE 802.3 CSMA/CD LAN Model

1000 BASE-T Basics

- Popularly known as Gigabit Ethernet (GigE)
- Still widely adopted and popular in Office and Industrial connectivity environment
- Four signal pairs for full-duplex transmission and reception over CAT-5 balanced cabling
- The transmission occurs at a data rate of 250 Mbps over each pair
- Employs a four-level, PAM5 encoding signaling scheme



1000 BASE-T Multi-Level PAM5 Encoded Signal

1000 BASE-T Core Measurements

- 1000 BASE-T tests are performed by setting the DUT in certain ‘test modes’ specified in the standard
- Test modes when enabled in the DUT helps to test waveform characteristics like Jitter, Distortion and get an insight into Eye diagram margins
- Test modes only change the data symbols provided to the transmitter circuitry; do not alter the electrical and jitter characteristics from those of normal operation

Test Mode	Test	IEEE 802.3 Reference
Test Mode-1	Peak Droop Template	40.6.1.2.1 40.6.1.2.2 40.6.1.2.3
Test Mode-2	Master Jitter	40.6.1.2.5
Test Mode-3	Slave Jitter	
Test Mode-4	Distortion MDI Return Loss MDI Common Mode Voltage	40.6.1.2.4 40.8.3.1 40.8.3.3

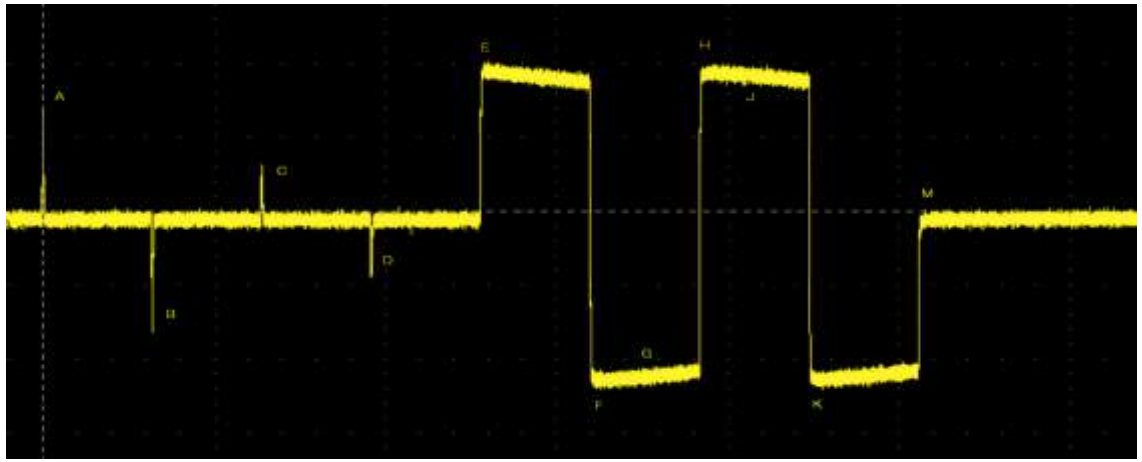
1000 BASE-T Test Modes

TEST MODE-1

- When test mode 1 is enabled, the PHY transmits a sequence of data symbols continually from all four transmitters
- This sequence is repeated continually without breaks between the repetitions when the test mode is enabled
- The Test Mode-1 is used to test for Template, Peak and Droop conformance tests

Sequence	Signal Level	Symbol Count
Sequence-1	1x +2	127x 0's
Sequence-2	1x -2	127x 0's
Sequence-3	1x +1	127x 0's
Sequence-4	1x -1	127x 0's
Sequence-5	128x +2, 128x -2, 128x +2, 128x -2	
Sequence-6		1024x 0's

1000BASE-T Test Mode-1 symbol table

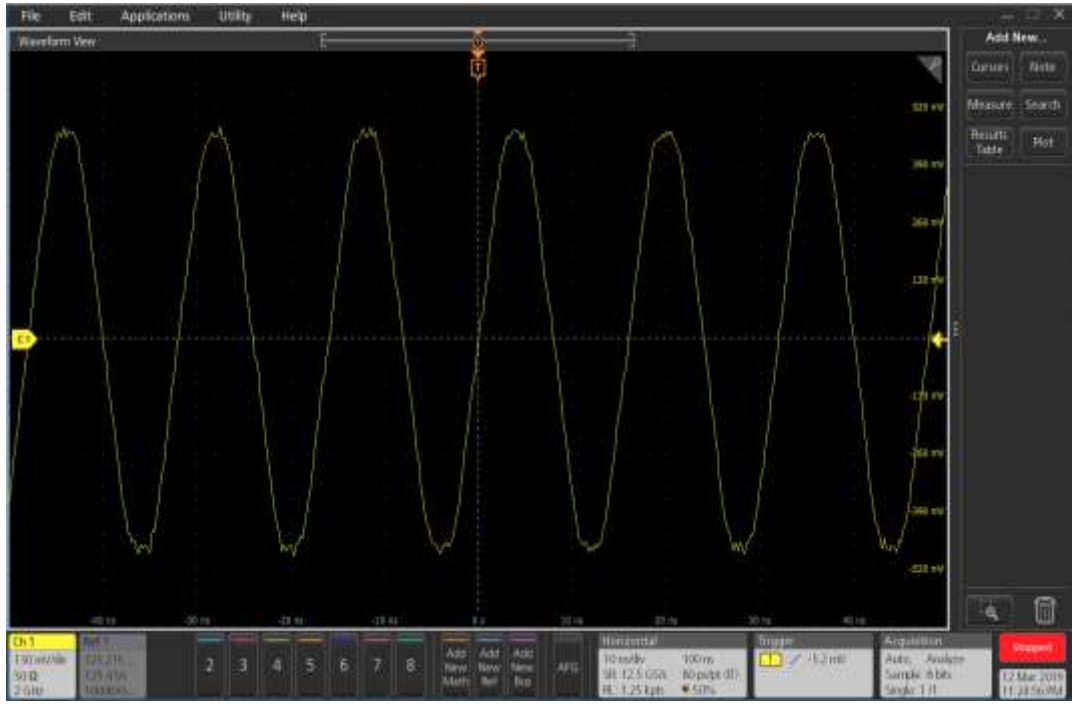


1000BASE-T Test Mode-1 waveform

1000 BASE-T Test Modes

TEST MODE-2 AND TEST MODE-3

- When test mode 2 is enabled, the Transmitter sends out the data symbol sequence of levels +2 and –2 repeatedly on all four channels
- The pattern looks similar to a clock pattern
- The transmitter times the transmitted symbols from a 125.00 MHz ± 0.01% clock in the Master timing mode
- The Test Mode-3 follows the same data symbol sequence as Test Mode-2 except that the transmitter times the transmitted symbols from a 125.00 MHz ± 0.01% clock in the Slave timing mode



1000BASE-T Test Mode-2 waveform

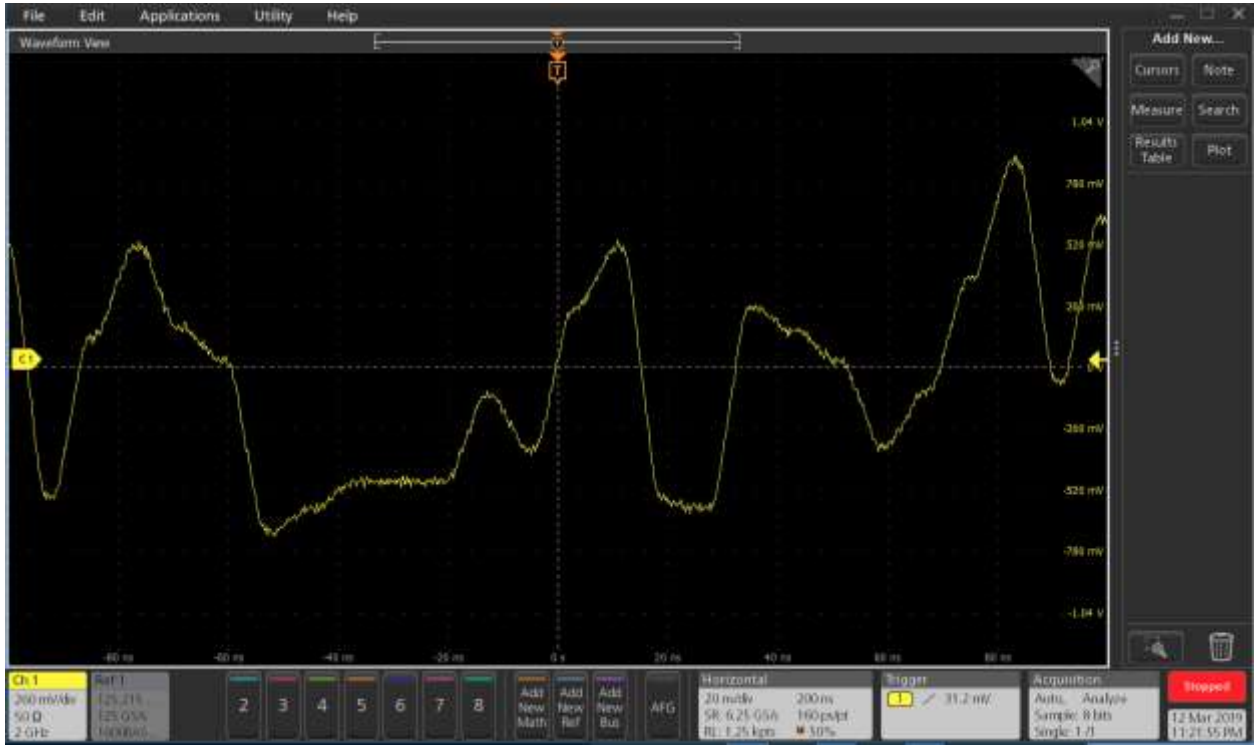
1000 BASE-T Test Modes

TEST MODE-4

- When Test Mode-4 is enabled, the transmitter sends out sequence of symbols generated by a scrambler generator polynomial, bit generation, and level mappings as defined in the IEEE spec

$$g_{s1} = 1 + x^{9} + x^{11}$$

- The maximum-length shift register used to generate the sequences defined by the polynomial is updated once per symbol interval (8 ns) resulting in a scrambled signal output.



1000BASE-T Test Mode-4 waveform

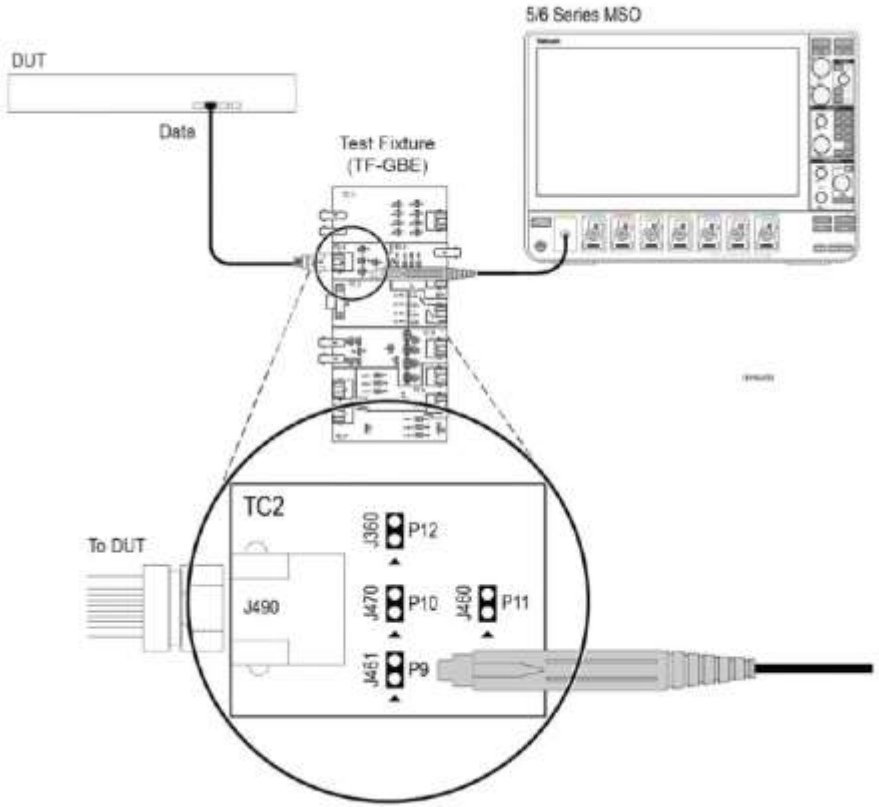
1000 BASE-T Measurements

CORE SCOPE BASED MEASUREMENTS

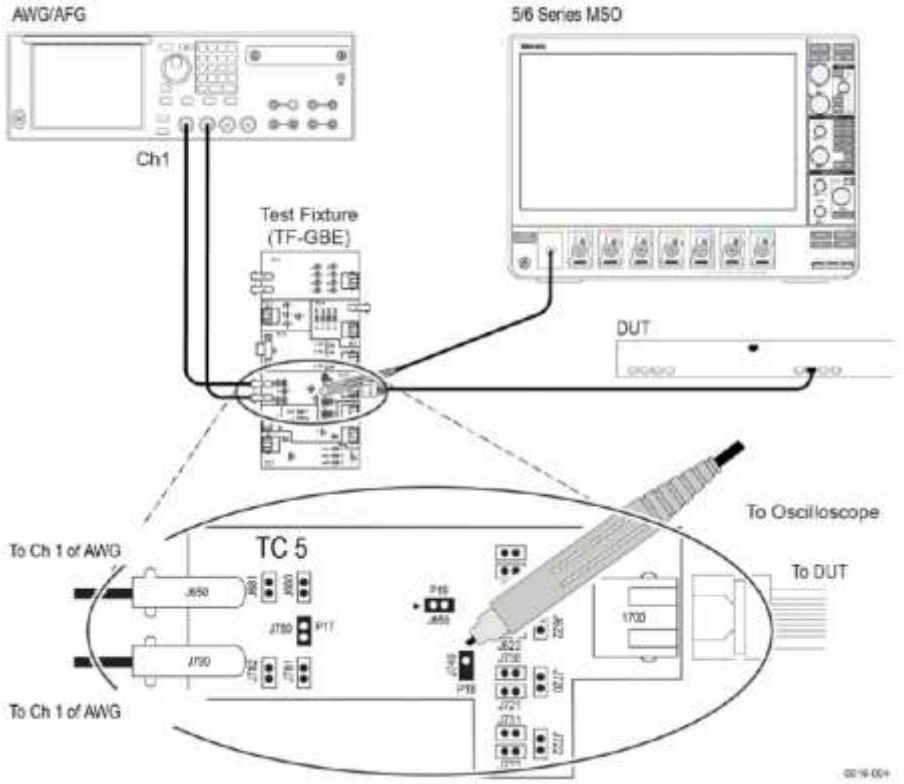
- Template (with and without disturber)
- Peak Volt (with and without disturber)
- Droop (with and without disturber)
- Distortion (with and without disturber; with and without clock)
- Jitter Master – Filtered and Unfiltered (with and without clock)
- Jitter Slave – Filtered and Unfiltered (with and without clock)
- CM Voltage
- Return Loss

1000 BASE-T Measurements

TEMPLATE, PEAK VOLT & DROOP (SETUP DIAGRAM)



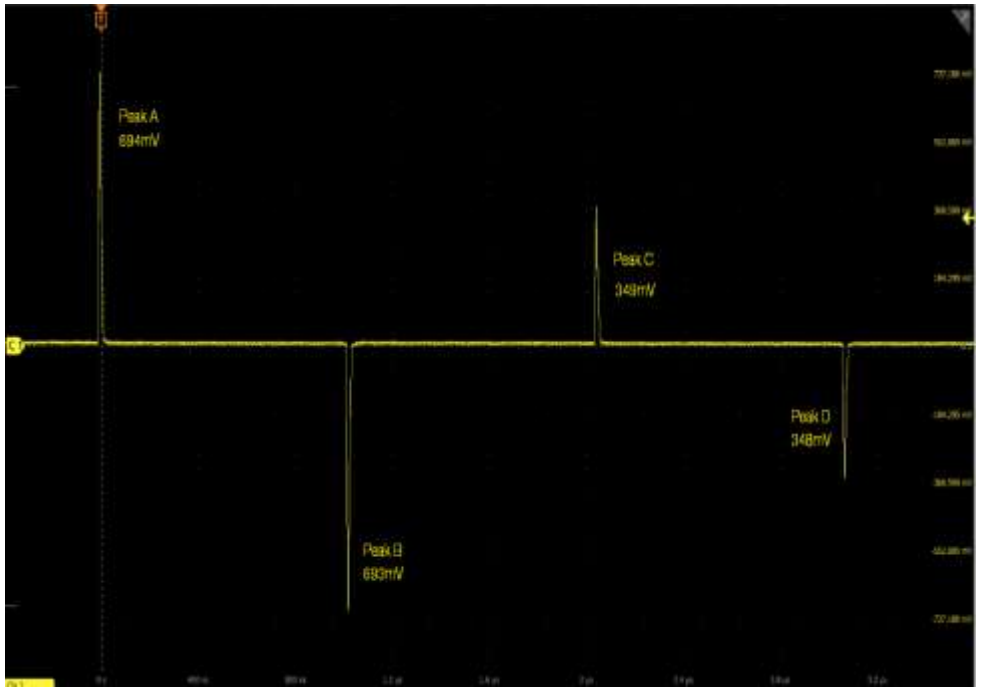
1000BASE-T Template, Peak Volt & Droop (without Disturber)



1000BASE-T Template, Peak Volt & Droop (with Disturber)

Peak

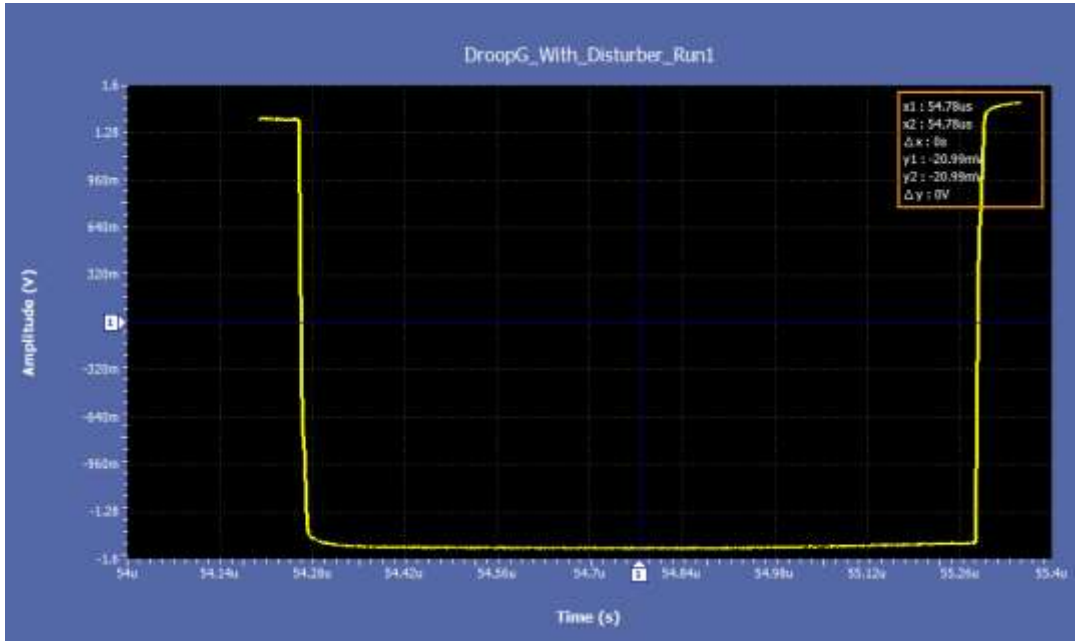
- The peak test is performed at the peak of the waveform at points A, B, C and D
- The criteria for passing the test is that that absolute value of the peak of the waveform at points A and B, must fall within the range of 670 mV to 820 mV (750 mV ± 0.83 dB)
- The absolute value of the peak of the waveforms at points A and B should differ by less than 1% from the average of the absolute values of the peaks of the waveform at points A and B
- The absolute value of the peak of the waveform at points C and D should differ by less than 2% from 0.5 times the average of the absolute values of the peaks of the waveform at points A and B



Peak points of 1000BASE-T Signal

Droop

- This test measures the voltage as a magnitude of the negative peak value of the waveform at point G.
- For a pass condition, the measured value should be greater than 73.1% of the magnitude of the negative peak value of the waveform at point F.
- Point G is defined as the point at a time base of 500ns after point F, where Point F is the point where the waveform reaches its minimum value.
- The same formula is used to compute Droop test results at points J and H.

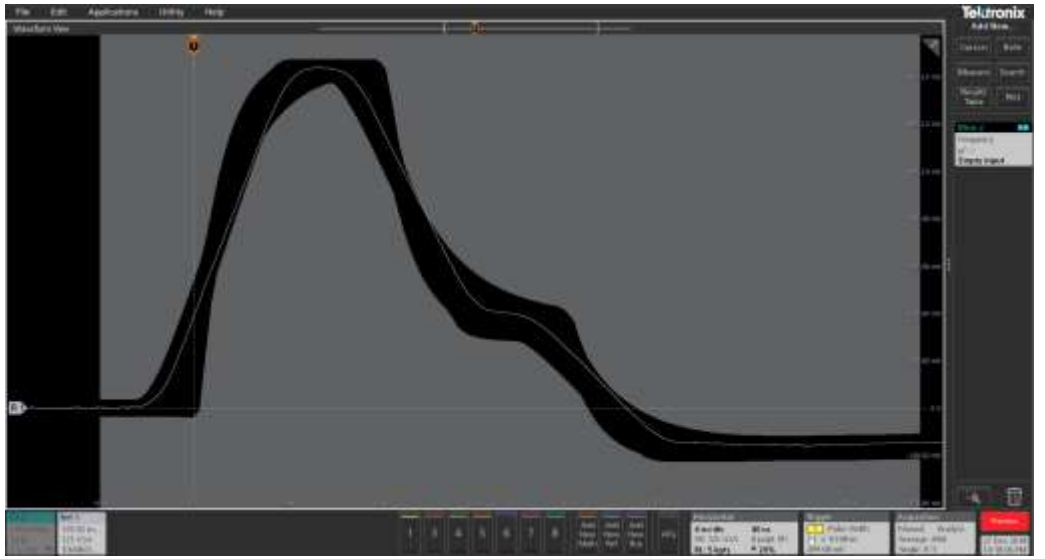


Result computed at Droop G point of 1000 BASE-T Signal

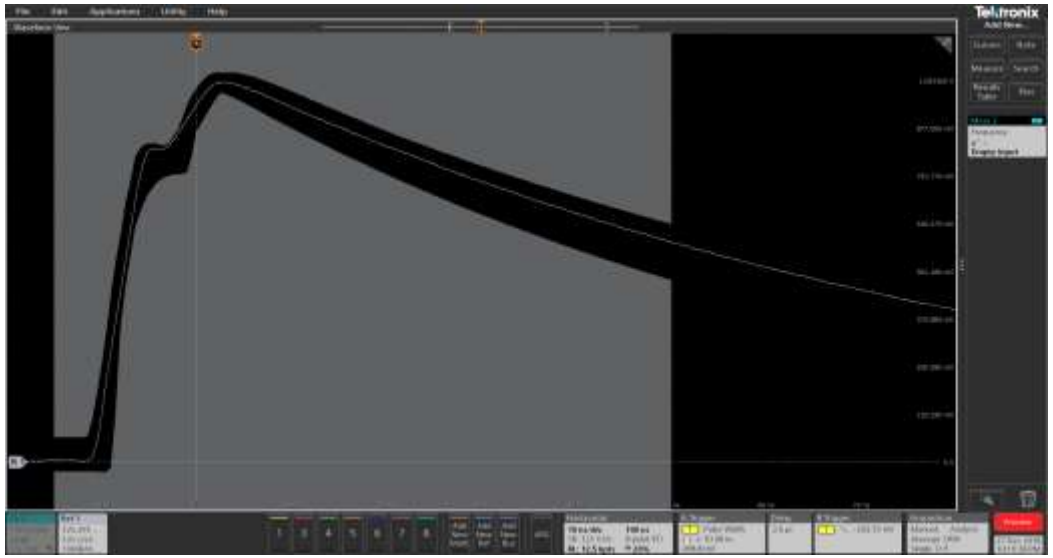
Template

- A template test is like a mask test which specifies the transmitter signal tolerance limits at each of the points A, B, C, D, F and H.
- The 1000 BASE-T spec defines template for each of the points and allows for waveforms to be shifted in time, as appropriate to fit within the template.
- A normalization setting is defined in the spec for each of the points

Waveform Points	Normalization Definition
Point A	WaveformA/VpeakA
Point B	WaveformB/VpeakA
Point C	WaveformC/(VpeakA/2)
Point D	WaveformD/(VpeakA/2)
Point F	WaveformF/VpeakF
Point H	WaveformH/VpeakH



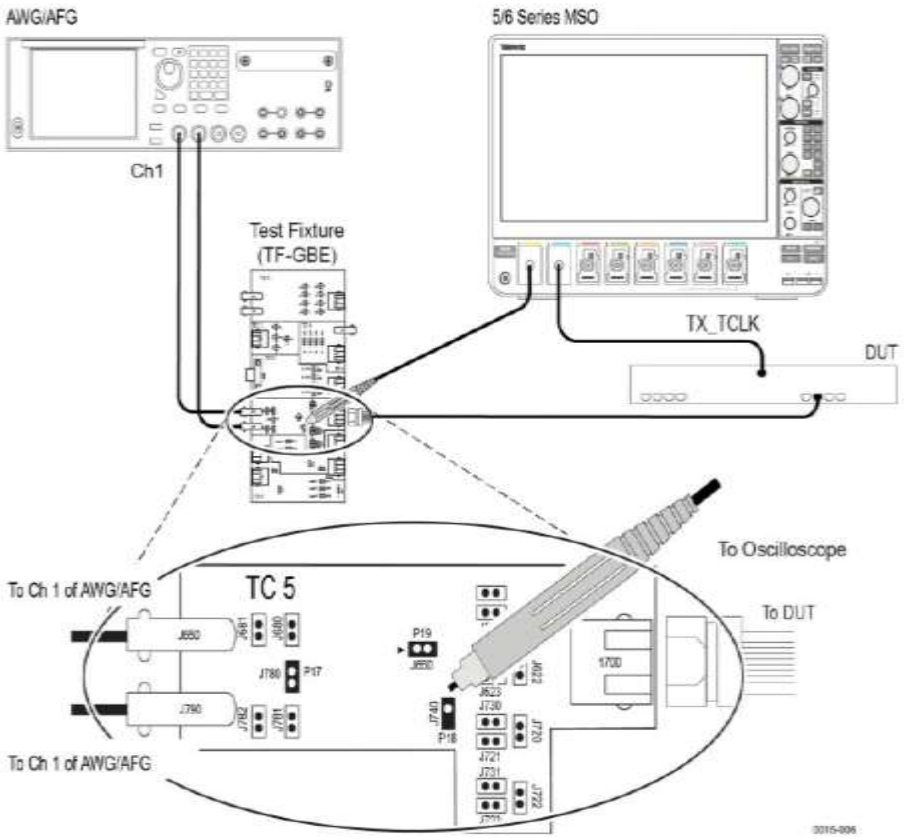
Template test at point A



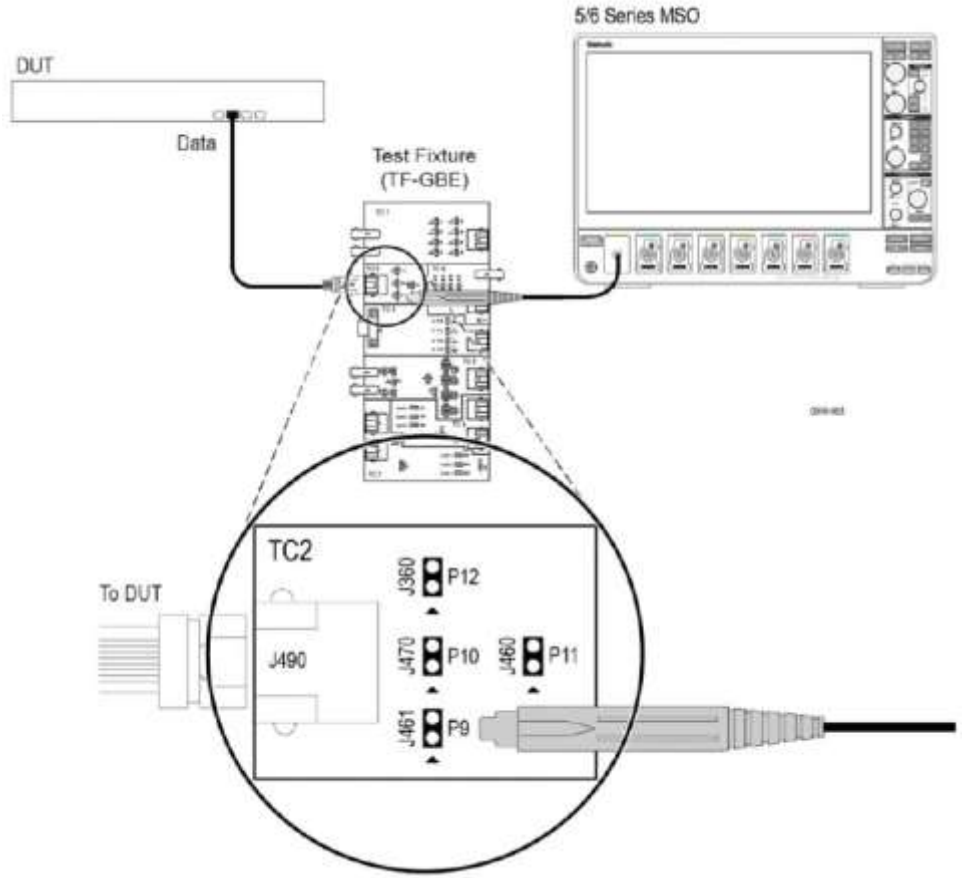
Template test at point F

1000 BASE-T Measurements

DISTORTION (SETUP DIAGRAM)



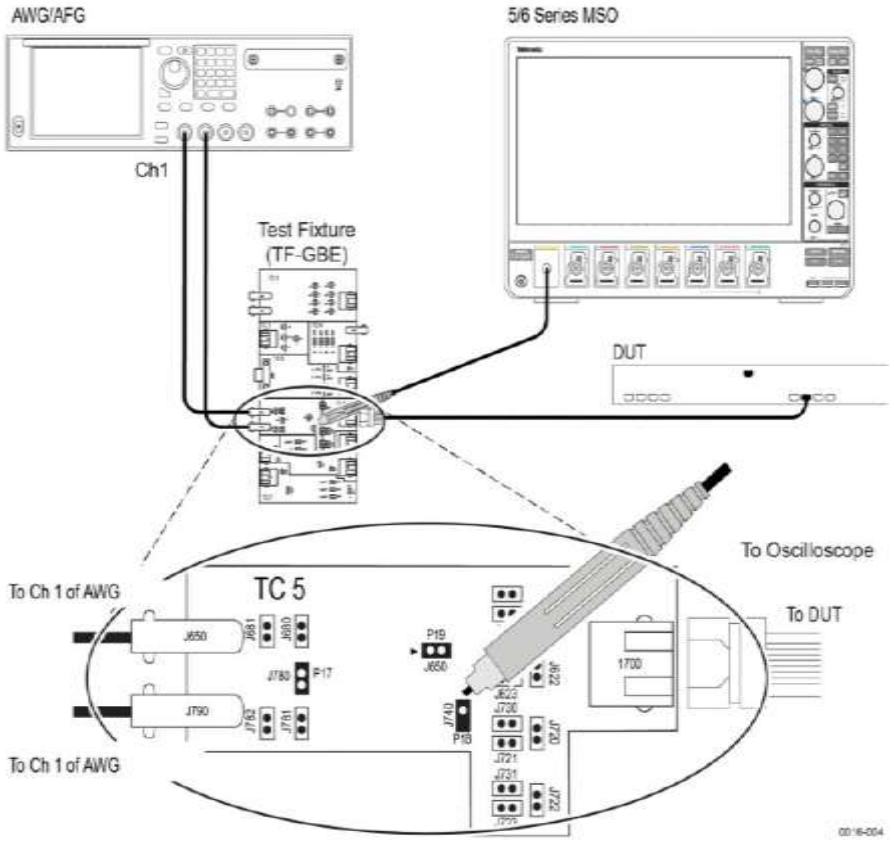
1000BASE-T Distortion (with Disturber; with clock)



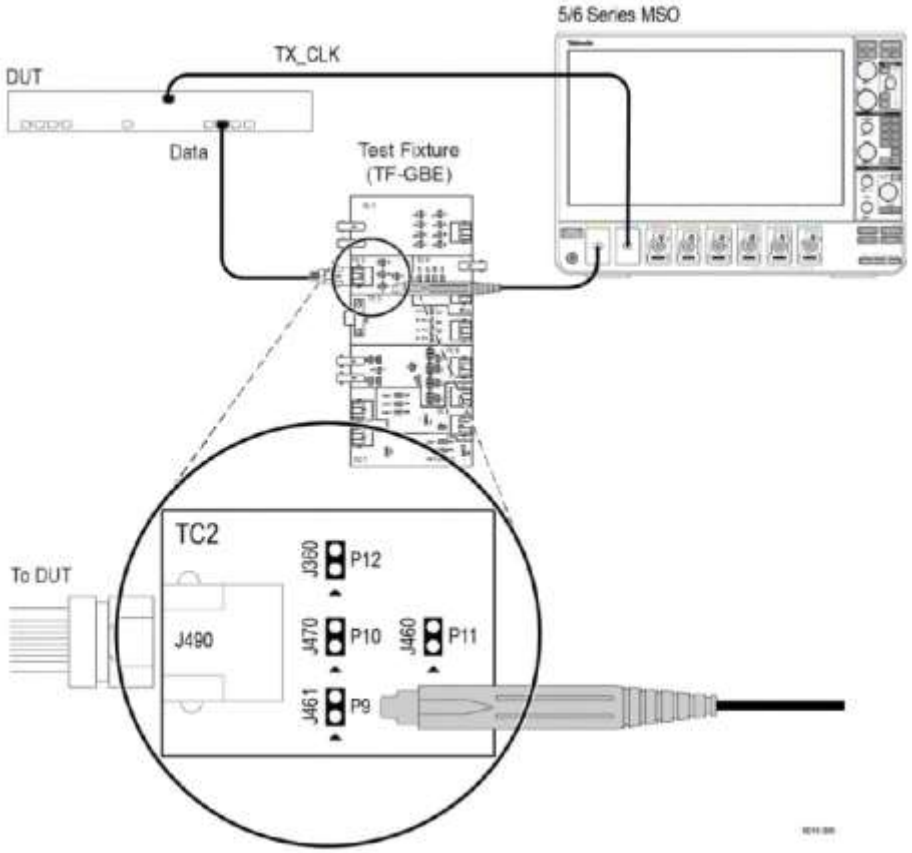
1000BASE-T Distortion (without Disturber; without clock)

1000 BASE-T Measurements

DISTORTION (SETUP DIAGRAM)



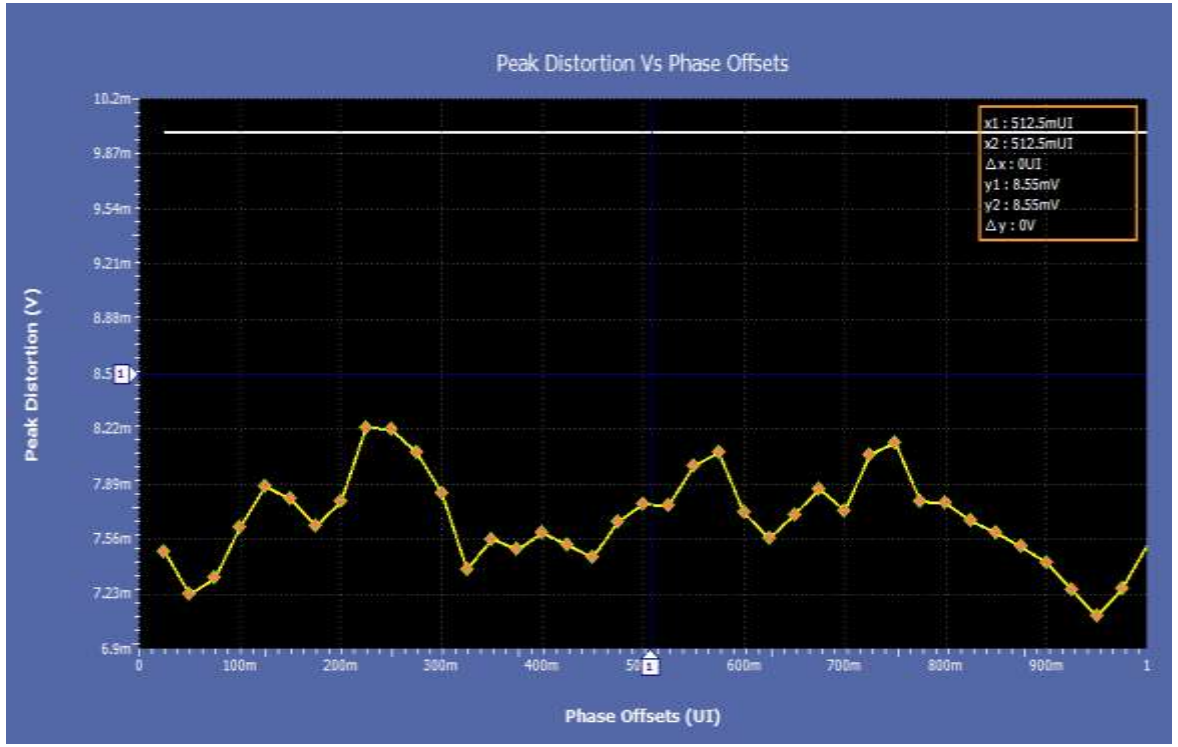
1000BASE-T Distortion (with Disturber; without clock)



1000BASE-T Distortion (without Disturber; with clock)

Distortion

- Distortion test is performed by putting the device under test in test mode 4 and observing the differential signal output at the MDI using transmitter test fixture, for each pair, with no intervening cable.
- For passing the test, the peak distortion must be less than 10 mV
- The peak distortion is determined by sampling the differential signal output with the symbol rate TX_TCLK at an arbitrary phase and processing a block of any 2047 consecutive samples with a block of code listed in IEEE specification

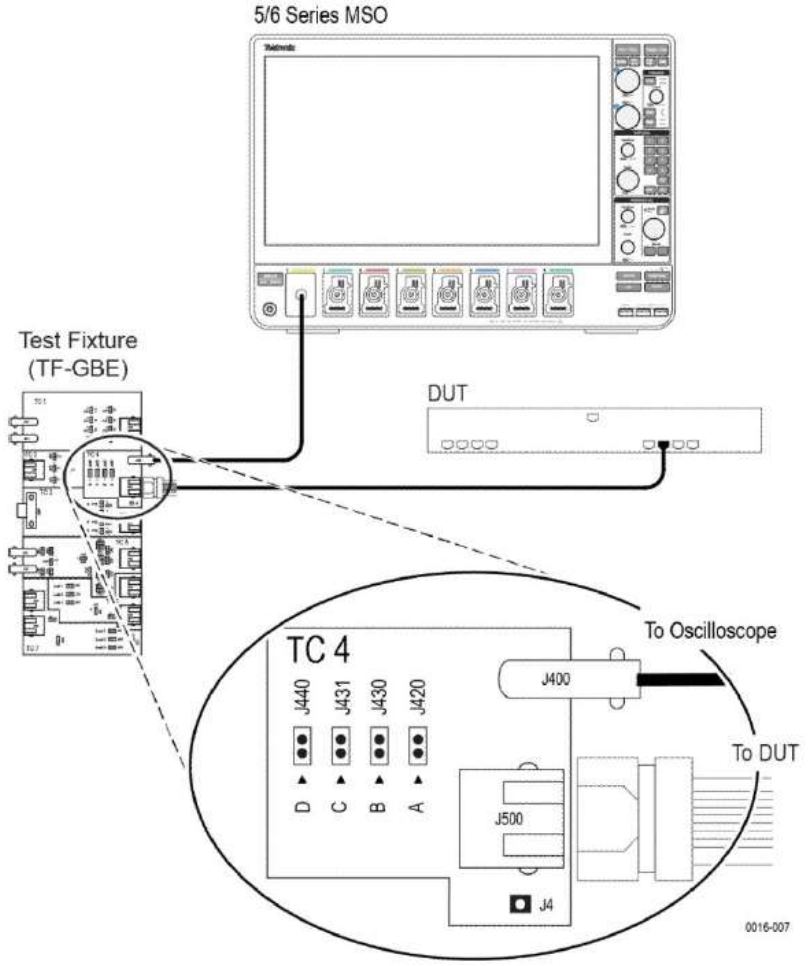


Transmitter Distortion without TX_CLK

Common Mode Voltage

- This test measures the magnitude of the total common-mode output voltage which must be less than 50mV peak-to-peak when transmitting data at frequencies above 1 MHz

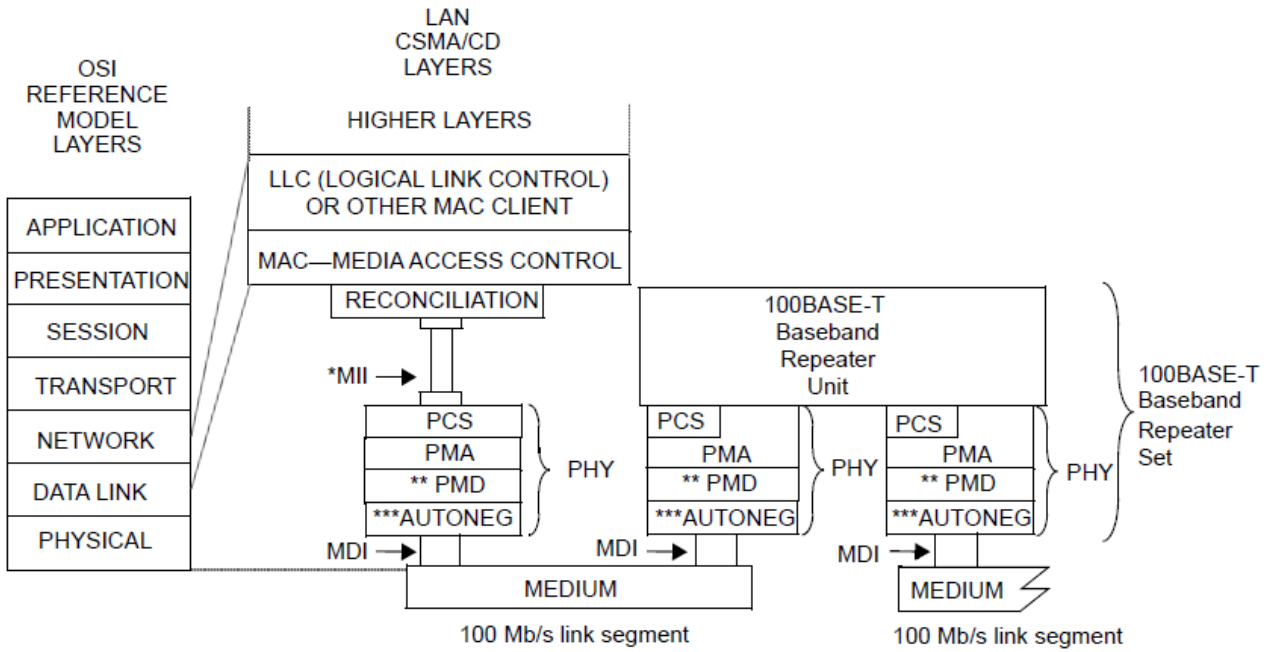
Waveform view of the CM Voltage test



1000 BASE-T Common Mode Voltage Test Setup

100 BASE-T
- Key Measurements

100 BASE-T Basics



MDI = MEDIUM DEPENDENT INTERFACE
MII = MEDIA INDEPENDENT INTERFACE

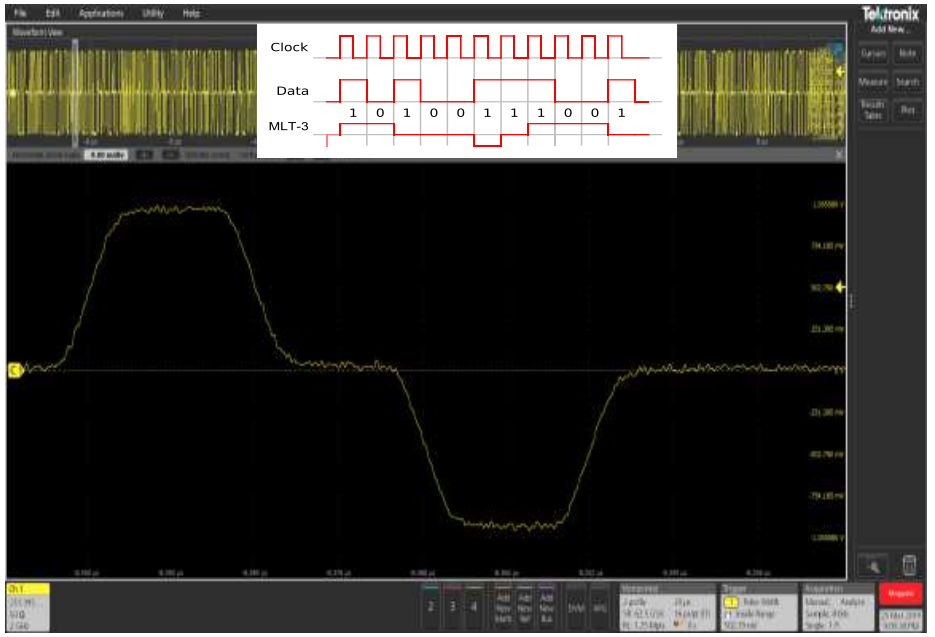
PCS = PHYSICAL CODING SUBLAYER
PMA = PHYSICAL MEDIUM ATTACHMENT
PHY = PHYSICAL LAYER DEVICE
PMD = PHYSICAL MEDIUM DEPENDENT

* MII is optional for 10 Mb/s DTEs and for 100 Mb/s systems and is not specified for 1 Mb/s systems.
** PMD is specified for 100BASE-X only; 100BASE-T4 does not use this layer.
Use of MII between PCS and Baseband Repeater Unit is optional.
*** AUTONEG is optional.

Figure 21–1—Architectural positioning of 100BASE-T

100 BASE-T Basics

- 100BASE-TX uses one signal pair for transmission and another pair for collision detection and receive.
- The transmission occurs at 125 MHz frequency operating at 80% efficiency.
- It employs a three-level, MLT-3 line encoding signaling scheme
- The ANSI X3.263 and IEEE 802.3 standards define the following array of compliance tests



100 BASE-TX Multi-Level Transmit 3 (MLT-3) Line Encoding

Domain	Test	ANSI X3.263 Reference
Amplitude	Output Voltage	9.1.2.2
	Overshoot	9.1.3
	Amplitude Symmetry	9.1.4
Return Loss	Return Loss	9.1.5
Time	Rise Time	9.1.6
	Rise Time	9.1.6
	Rise/Fall Time	9.2.6
Jitter	Total Transmit Jitter	9.1.9
	Duty Cycle Distortion	9.1.8
Both	Template	Annex J

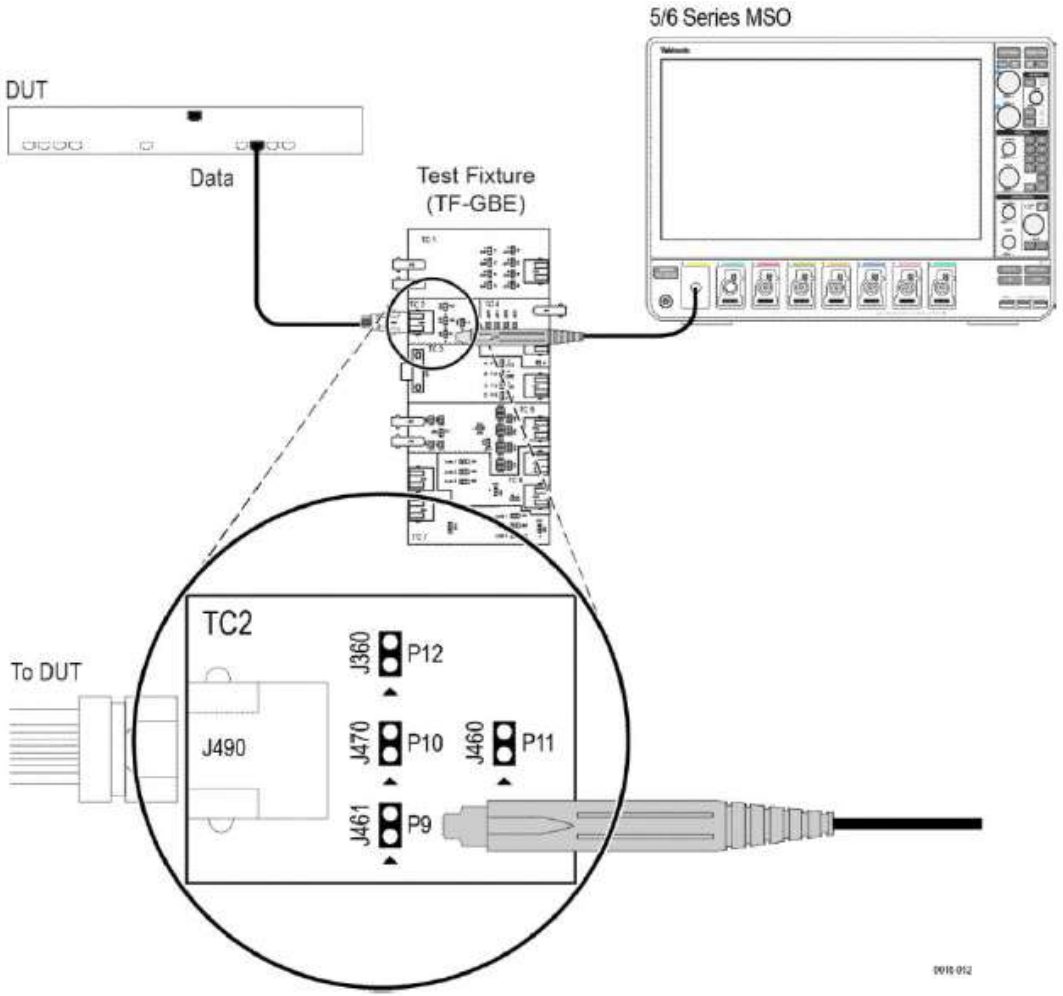
100 BASE-T Measurements

CORE SCOPE BASED MEASUREMENTS

- Template
- Differential Output Voltage
- Signal Amplitude Summary
- Rise and Fall Time
- Rise/Fall Time Symmetry
- Waveform Overshoot
- Jitter
- Duty Cycle Distortion
- Return Loss

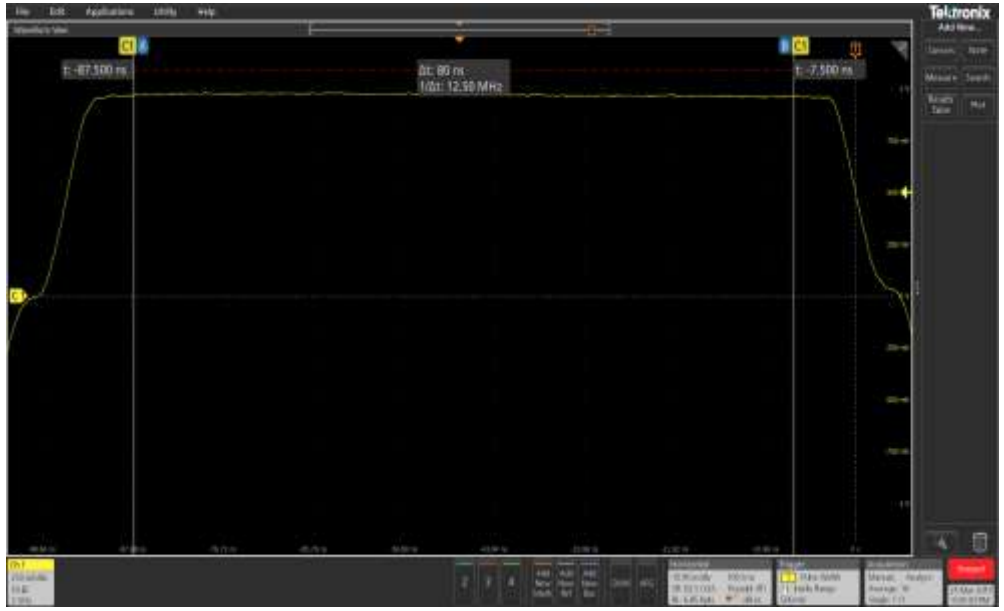
100 BASE-T Connection Diagram

FOR ALL SCOPE BASED TESTS



100 BASE-T Amplitude Domain Tests

- These tests are performed on the portion of the random packet signal that generates a pulse going from 0V to Vout (positive and negative).
- For reliable measurement, the test is performed on the longest pattern with no transition.
- The standard describes 112 ns pulse (14-bit pattern) for this purpose. However, these patterns may not be easily available.
- Both are positive and negative pulses duration are tested

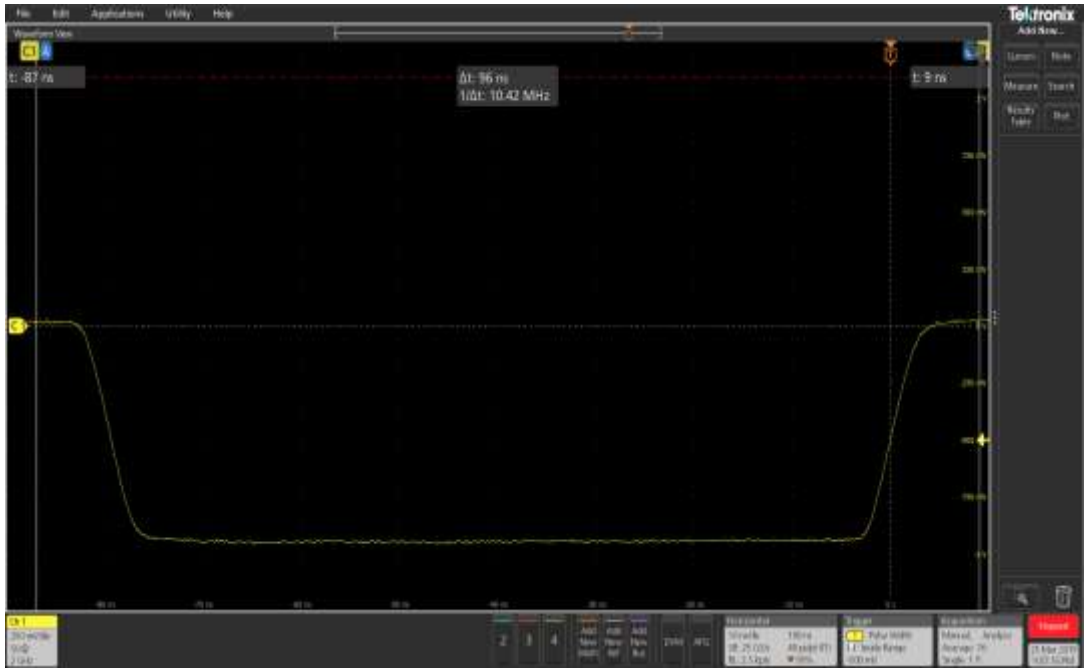


Amplitude tests performed on long run of logic high levels

Signal is termed “rising” when transitioning from the baseline voltage to either +Vout or –Vout, and is termed “falling” when transitioning from either +Vout or -Vout to the baseline voltage.

100 BASE-T Time Domain Tests

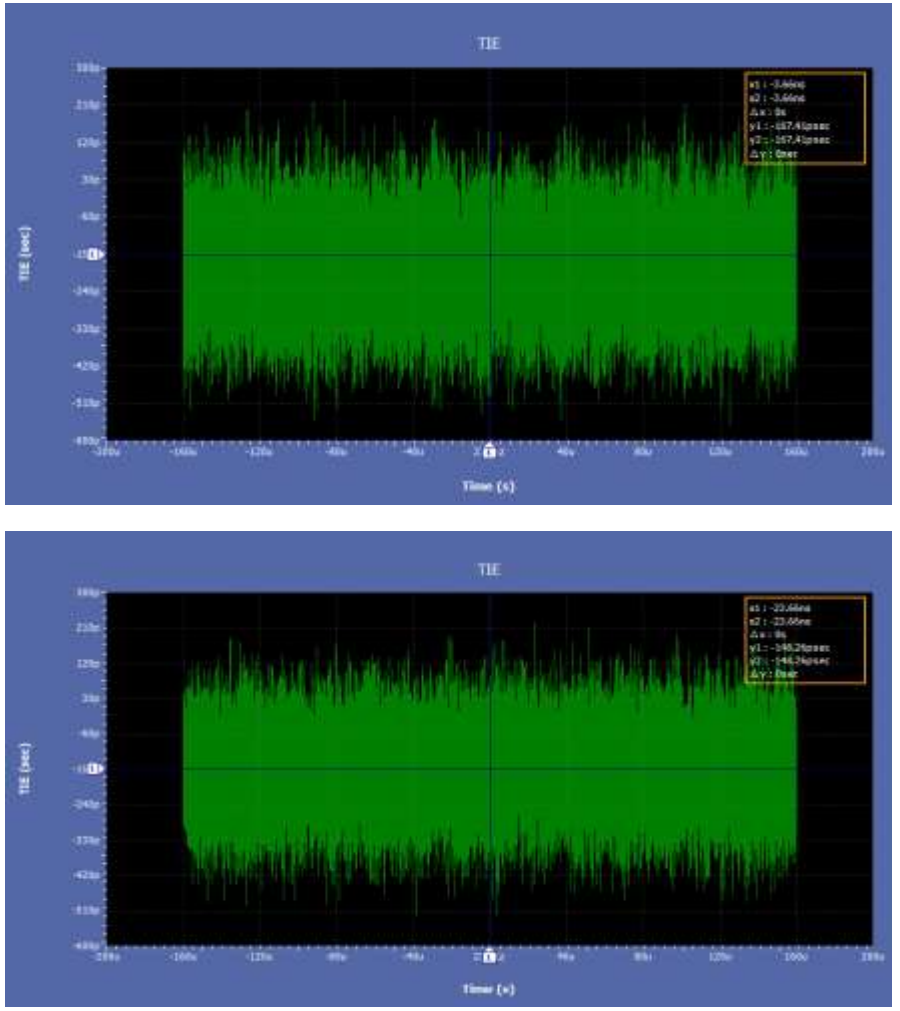
- The waveform region is selected such that rise and fall times of the signal are minimally affected by the ISI.
- A longest pulse that is preceded and succeeded by at least two consecutive symbols at baseline voltage is chosen
- Both positive and negative pulses of 80 ns (10 bits times 8 ns) duration are considered



10 consecutive bits for rise/fall time measurements

100 BASE-T Jitter

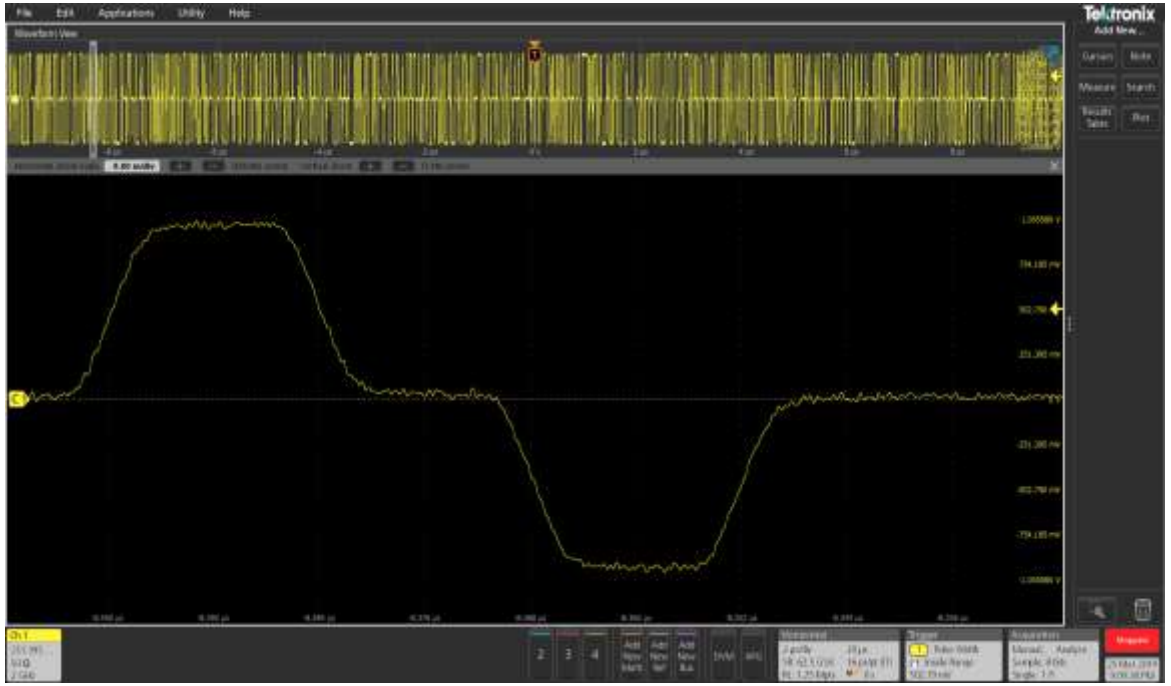
- For 100 BASE-T Jitter, the Peak-to-peak jitter is measured using scrambled IDLEs or HALT line state.
- The most common method for the jitter test is calculating the Time Interval Error (TIE) which is difference between recovered edge time and actual edge time.
- TIE is calculated for the upper and lower half of the waveform and the peak to peak value is reported.
- The result needs to be lower than 1.4ns for the test to pass.



Positive and Negative Jitter measured using TIE Jitter Method

100 BASE-T Duty Cycle Distortion (DCD)

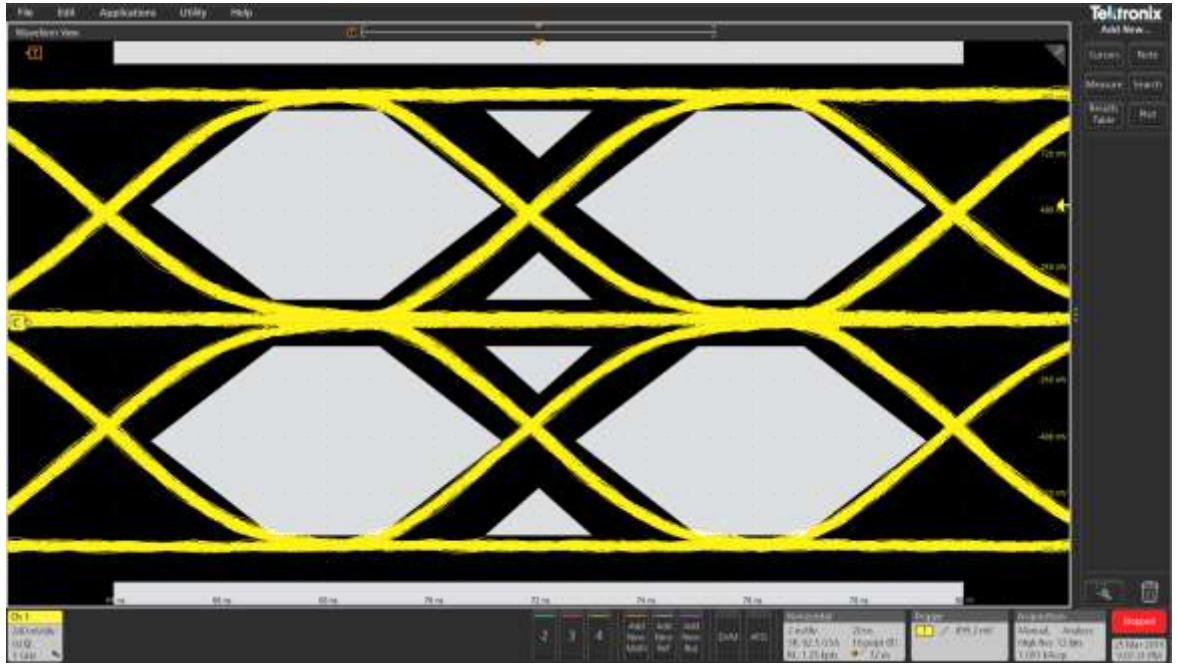
- The system is driven with a determined clock-like pattern (such as 0-1-0-1-0-1-0-1).
- DCD is measured at portions of the signal where the four successive MLT-3 transitions generated by a 0-1-0-1 NRZ bit sequence that is preceded and succeeded by at least two consecutive symbols at the baseline voltage
- The pattern has widths of positive and negative polarity MLT-3 pulses that are 16 ns wide



Test pattern for Duty Cycle Distortion test

100 BASE-T AOI Template Test

- For 100BASE-TX, the AOI Template Mask is defined so that the signal distortions such as overshoot, jitter, incorrect rise and fall times, etc., will cause the mask test to fail.
- The specifications in Annexure J also specify a tolerance of 5% on the mask geometries.



Testing positive and negative side, simultaneously for AOI Template test

10 BASE-T
- Key Measurements

10 BASE-T Basics的OSI模型

数据链路层中的MAC子层以及物理层

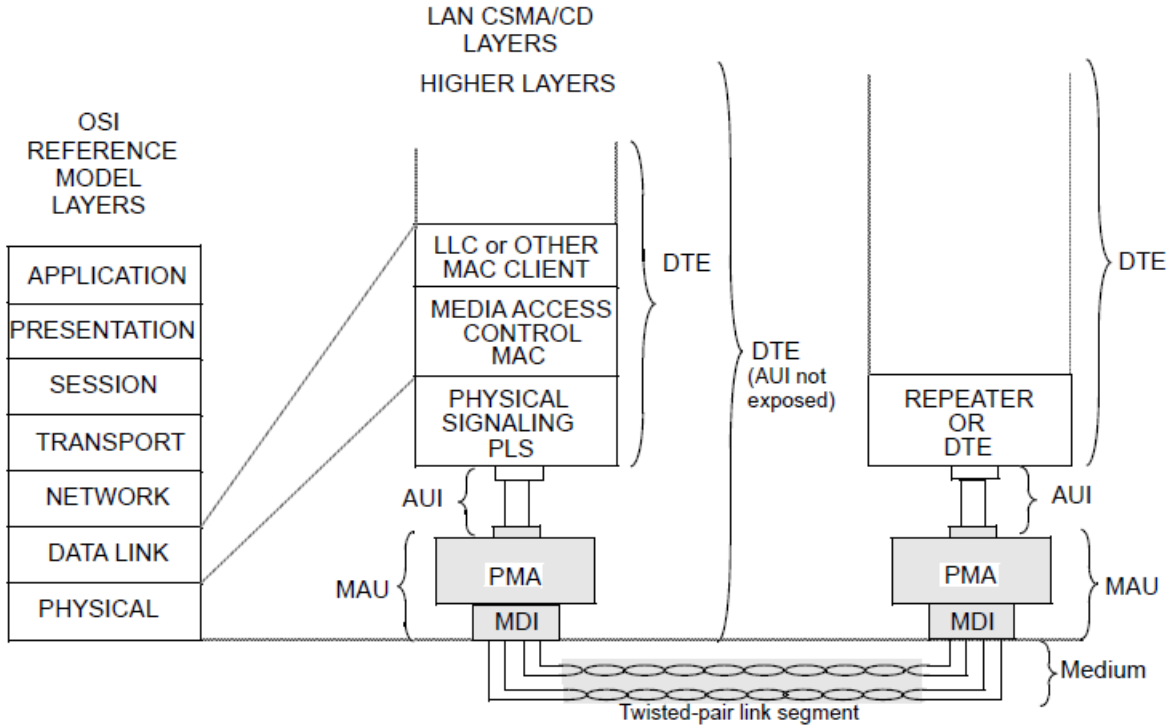
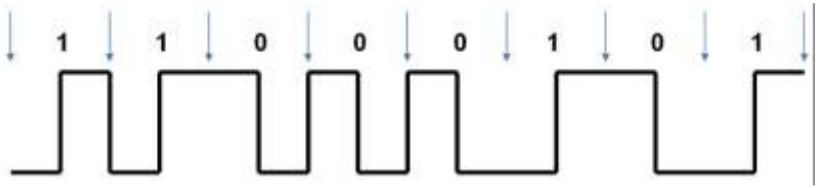


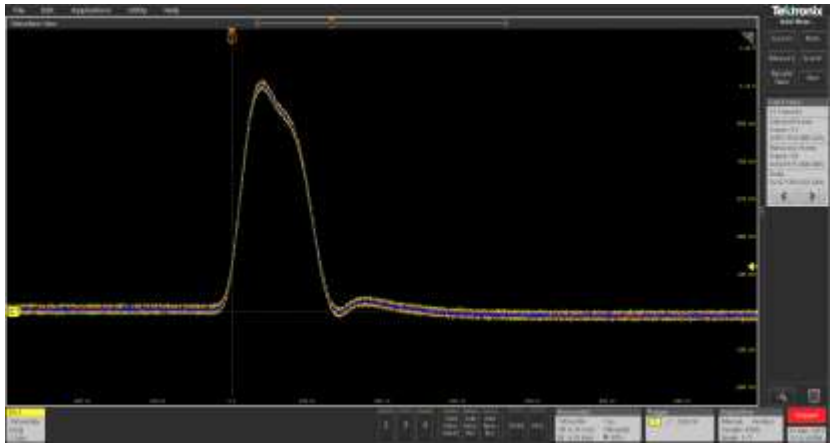
Figure 14–1—10BASE-T relationship to the ISO/IEC Open Systems Interconnection (OSI) reference model and the IEEE 802.3 CSMA/CD LAN model

10 BASE-T Basics

- Uses Category 3 (CAT3) cable or better with two unshielded twisted-pair (UTP) wires. These twisted-pair wires are referred to as the ‘Media’ in the IEEE specifications
- One pair is for Tx and the other pair is for Rx. Each pair is a differential signal. None of the cable wires are connected to ground at the network nodes.
- 10BASE-T is Manchester encoded data in which data and clock signals are combined to form a single self-synchronizing data stream.
- A transition always occurs in the middle of each bit and the bit cell period is 100 ns.
- After the start of TP_IDL there are no transitions (differential voltage remains at 0 mV ± 50 mV) until the next Ethernet frame or link test signal.
- During TP_IDL the 10BASE-T link test pulse is transmitted every 16 ms ±8 ms. The link test pulse signal is a positive pulse 585 mV to 3.1V and it is a minimum of ~60 ns wide and a maximum of ~200 ns wide.



10BASE-T Manchester 11000101 coding with a transition in the middle of each bit.



10BASE-T Link test pulse, transmitted every 16ms ±8ms and is ~60ns to ~200ns wide

Positive link pulse confirms the differential probe is correctly connected to the Ethernet 10BASE-T twisted pair

10 BASE-T Measurements

Test Reference : Subclause 14.3.1.2.1 of IEEE standard 802.3-2002 (for 10BASE-Te, refer to IEEE standard 802.3az)

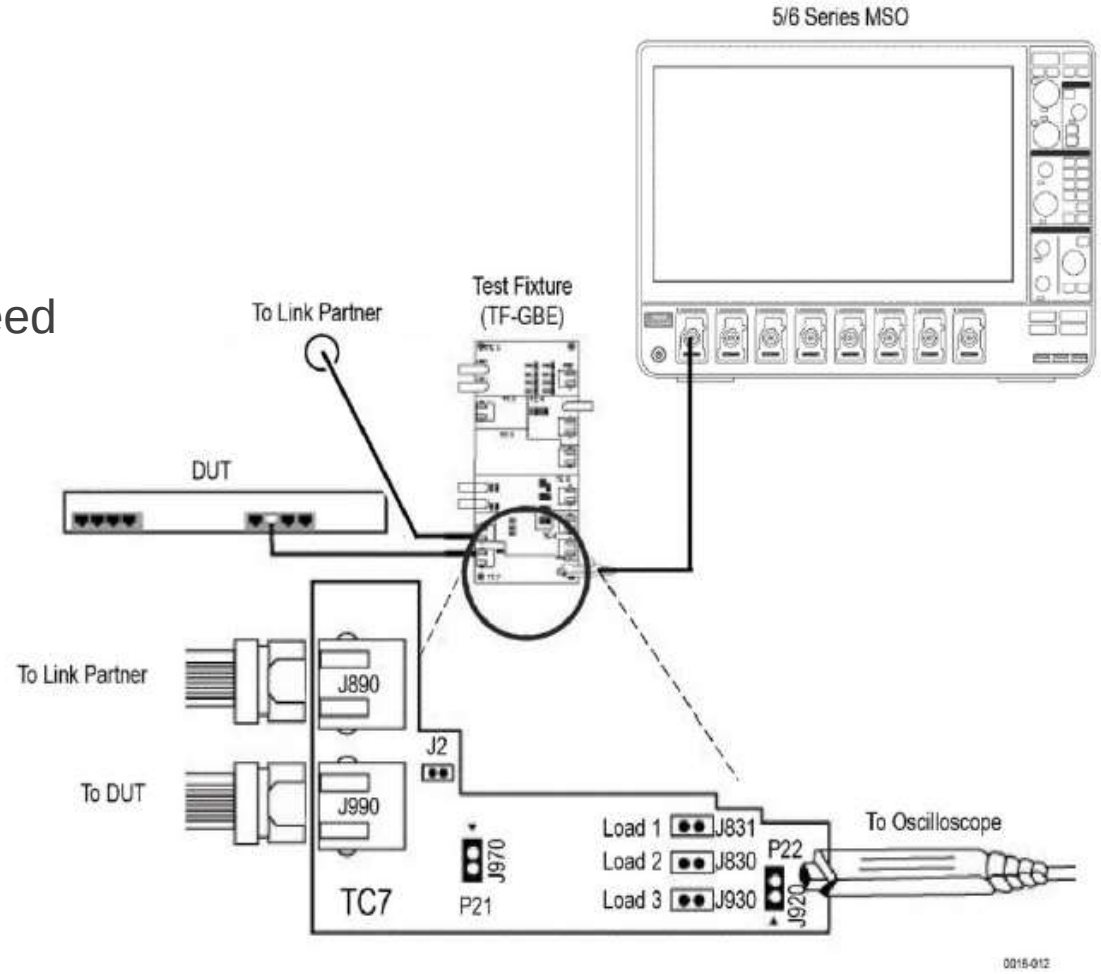
CORE SCOPE BASED MEASUREMENTS

- Template
  - MAU
  - Link Pulse
  - TP_IDL
- Differential Voltage
- Harmonic
- Jitter (with and without cable)
- CM Voltage
- Return Loss

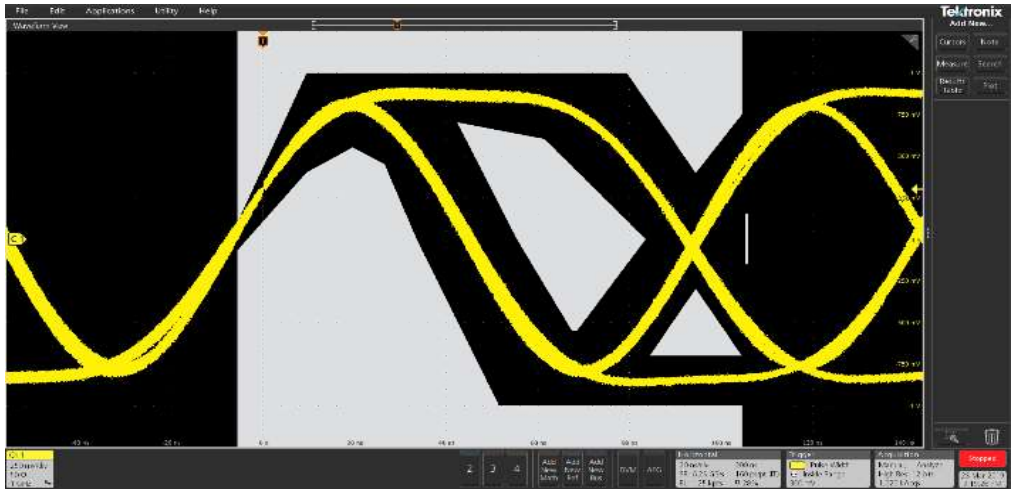
10 BASE-T Measurements

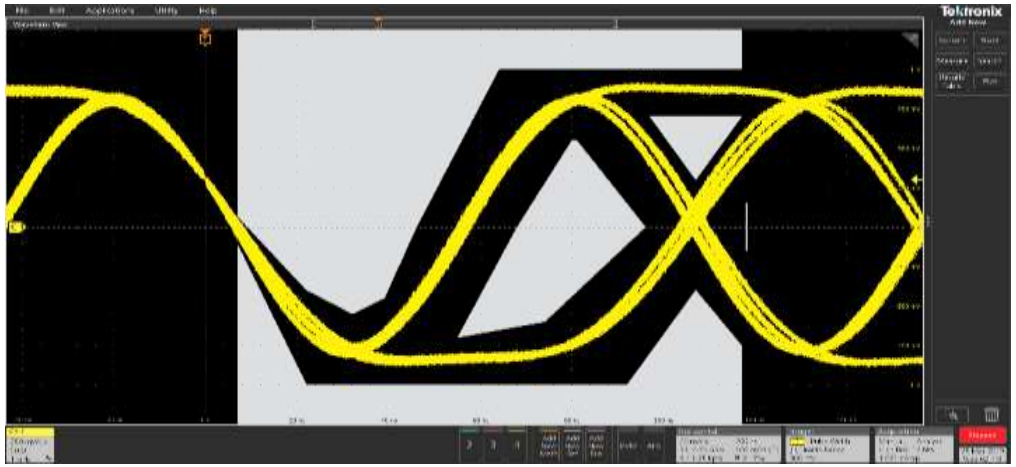
MAU, TP_IDL LOAD WITH TPM, AND LINK PULSE LOAD WITH TPM

The standard permits scaling the MAU templates by a factor of 0.9 to 1.1. The TP_IDL and Link Pulse tests need to be performed with and without a Twisted Pair Model (TPM) as defined by the standard.

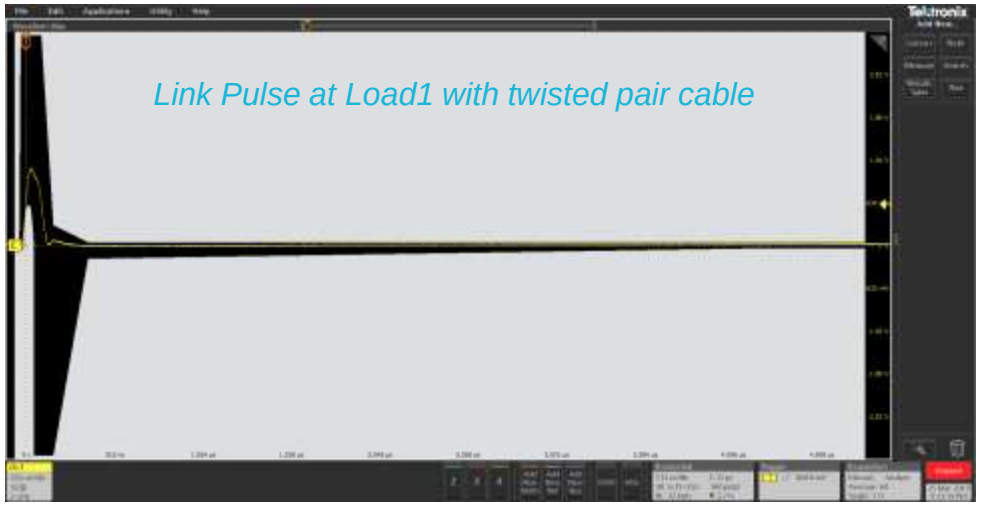


10 BASE-T Template

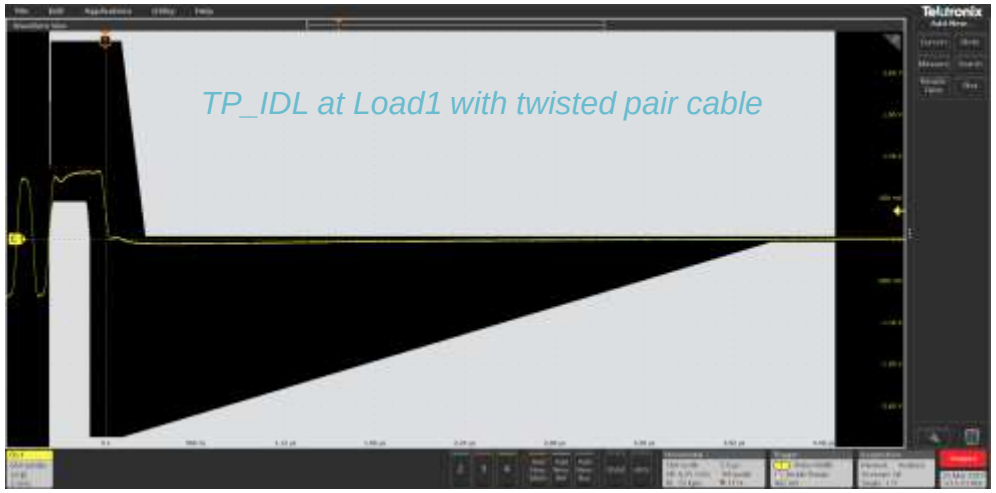




MAU Template test – Internal (Top) and Inverted (Bottom)



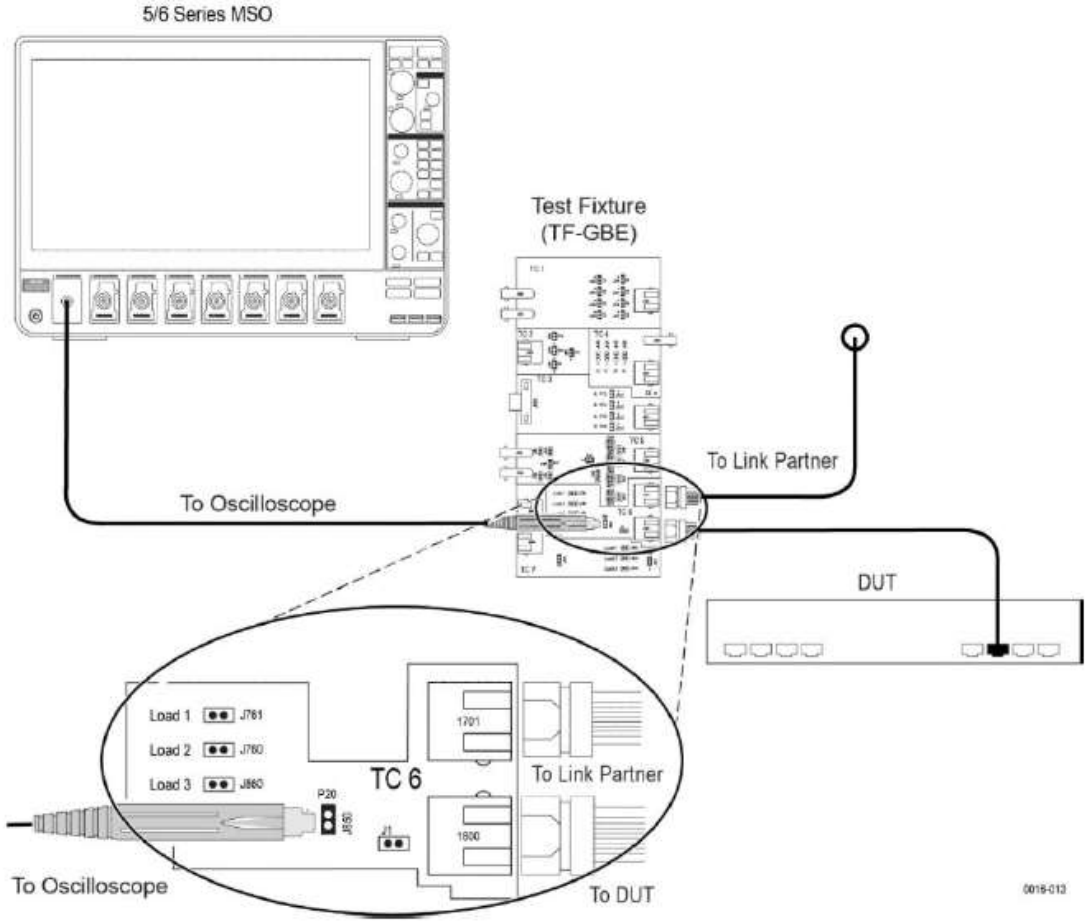
A LTP should be bounded between ±3.1V with a width of no greater than 42 Bit Times (4200 ns)



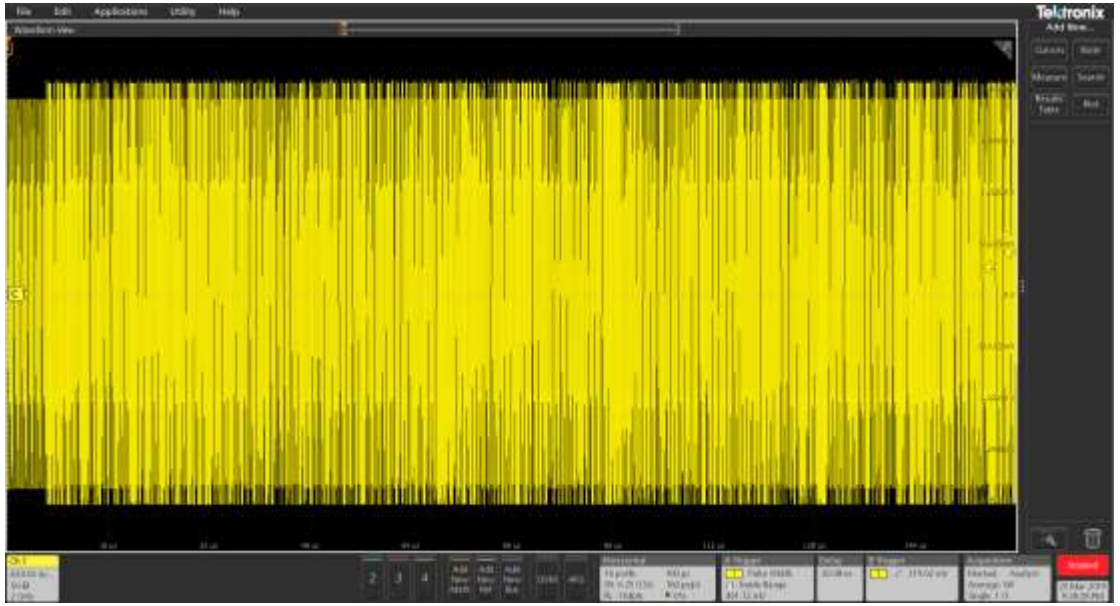
The Start of Idle (SOI or Start of TP_IDL) occurs at the end of a packet and shall always begin with a positive waveform.
The SOI indicates when the end of a packet and the beginning of idle.
The SOI shall fit with in the template below when connected to a load.

10 BASE-T Measurements

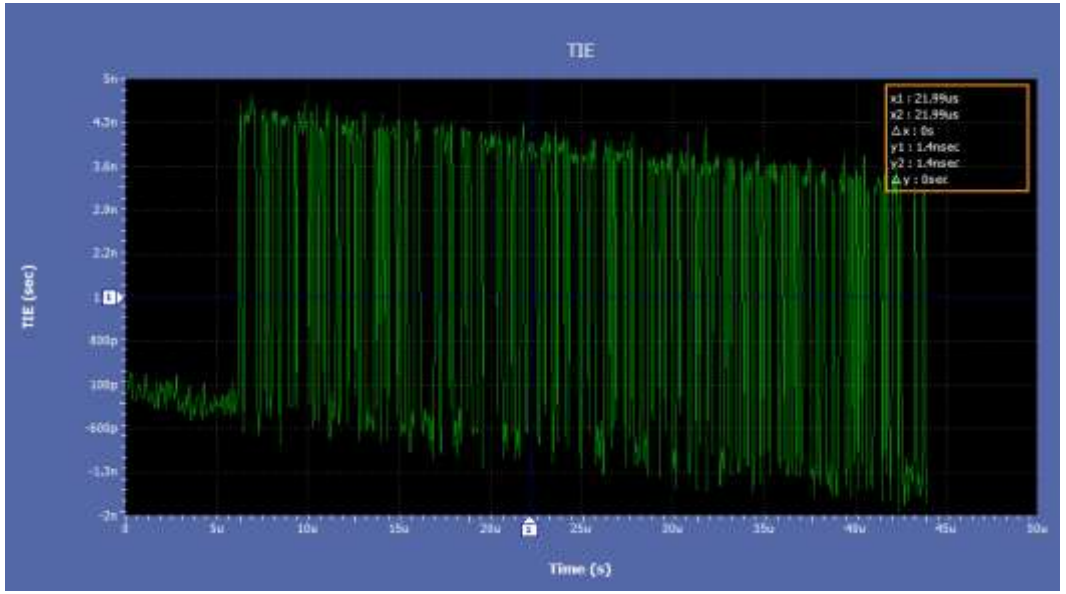
TP_IDL LOAD WITHOUT TPM, LINK PULSE LOAD WITHOUT TPM, HARMONIC, AND DIFFERENTIAL VOLTAGE



10 BASE-T Measurements



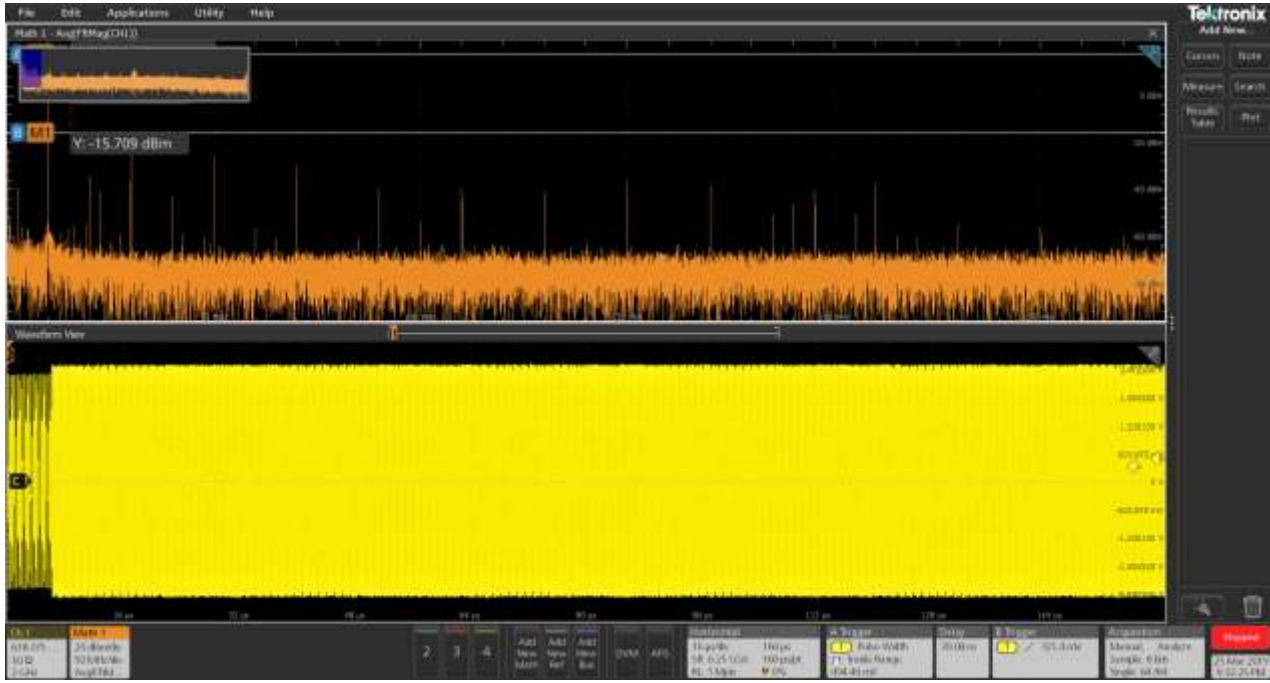
The peak differential voltage a device transmits shall be between 2.2V and 2.8V. This means the height of a frame should never be below –2.8 volts and above +2.8 volts or should never be below 2.2 volts and above –2.2 volts.



Jitter is measured at the 8 and 8.5 Bit times with and without the TPM present. With out the TPM a zero crossing should occur ±20ns at the 8 and 8.5 BT. With the TPM a zero crossing should occur ±11 ns at the 8 and 8.5 BT.

10 BASE-T Harmonics

- When monitoring a series of all ones (or all zeroes) on the TD circuit, each harmonic shall be at least 27 dB below the 10 MHz fundamental.
- Compute the power contained within the fundamental frequency component of the all-zeros portion.
- Compute the power contained within the other harmonics within the frequency spectrum of the all-zeros portion
- All of the harmonics shall be at least 27 dB below the fundamental



Return Loss

Return Loss Testing

The return loss of the cabling system can affect interoperability of the system.

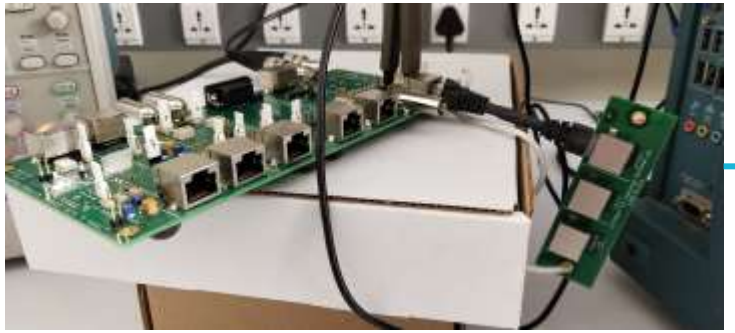
The Ethernet standard defines the minimum amount of attenuation the reflected signal should have relative to the incident signal. The Return Loss test measures the impedance, typically over the range of 100 Ω ±15%.

TekExpress Ethernet software performs the Return Loss test for 85, 100, and 115 Ω (111 Ω for 10BASE-T) impedances as prescribed by the standard, using the 5/6 Series MSO and AFG/AWG series used for other tests, enabling efficient usage of resources.

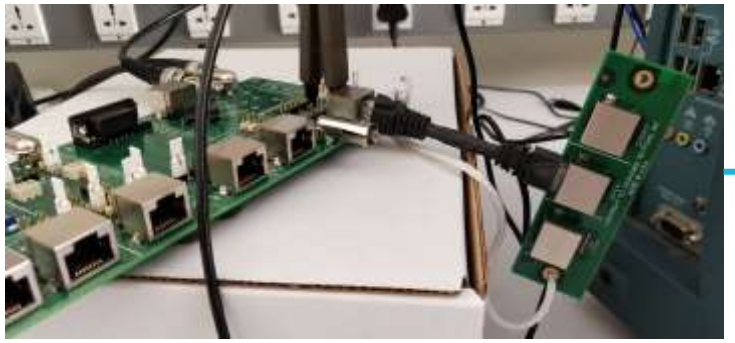
Return Loss Calibration

Probing Point: TC1 on the TF-GBE-BTP fixture.
P1 and P2 for Tx RL; P3 and P4 for Rx RL

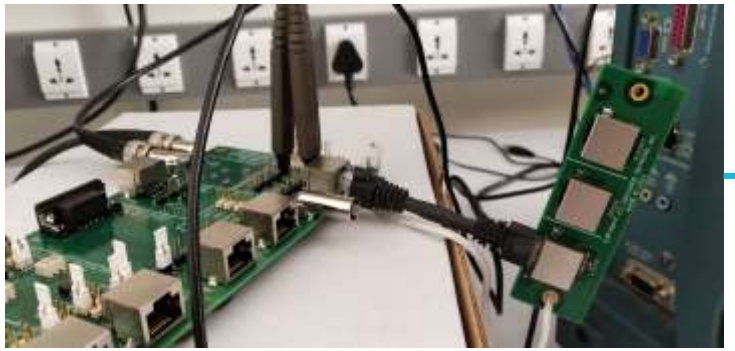
Step-1 : SHORT



Step-2 : OPEN

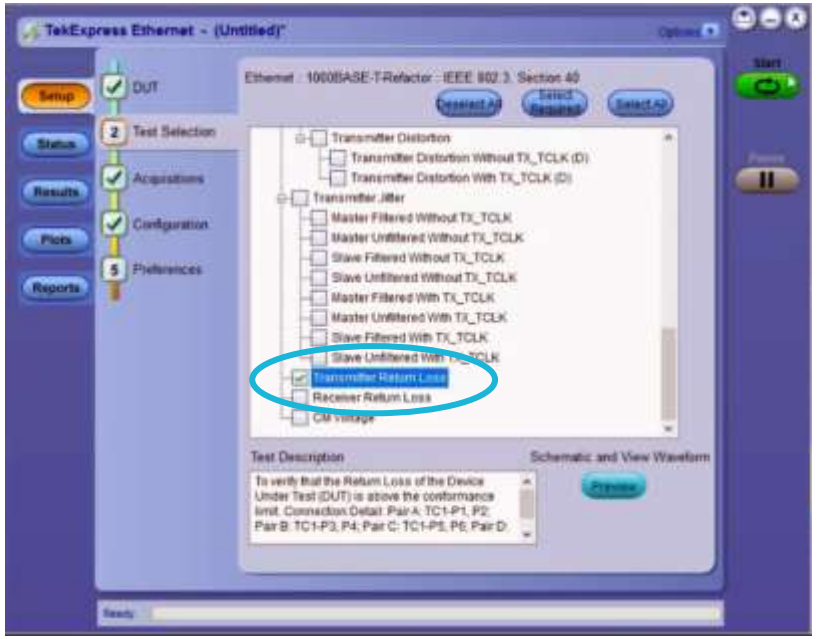


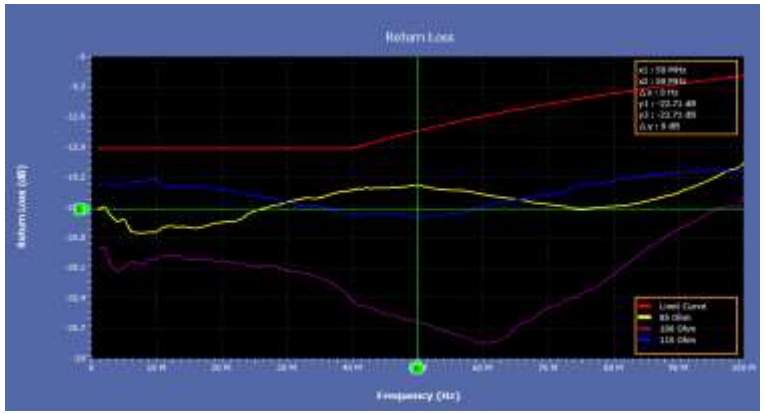
Step-3 : LOAD



Return Loss Test

- Once the Return Loss calibration is completed, apply the calibration so the calibration coefficients can be applied during testing.
- Disconnect the cable from calibration fixture and connect to the DUT
- Perform Automated Return Loss testing using TekExpress Ethernet software

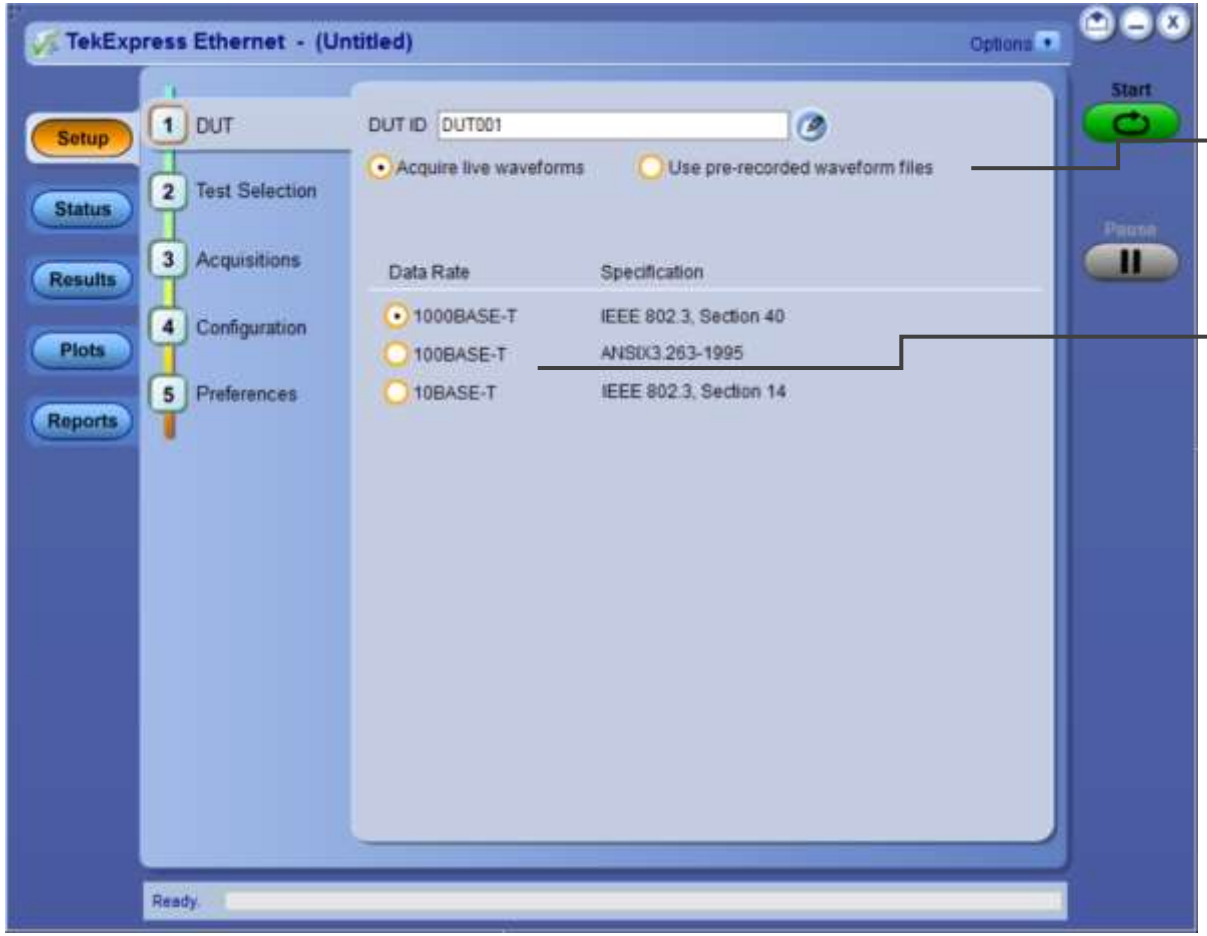




TekExpress Ethernet

Panels

DUT PANEL



Choose, Live of Offline Analysis (some tests like Template only run in Live mode)

Choose the Ethernet test speed

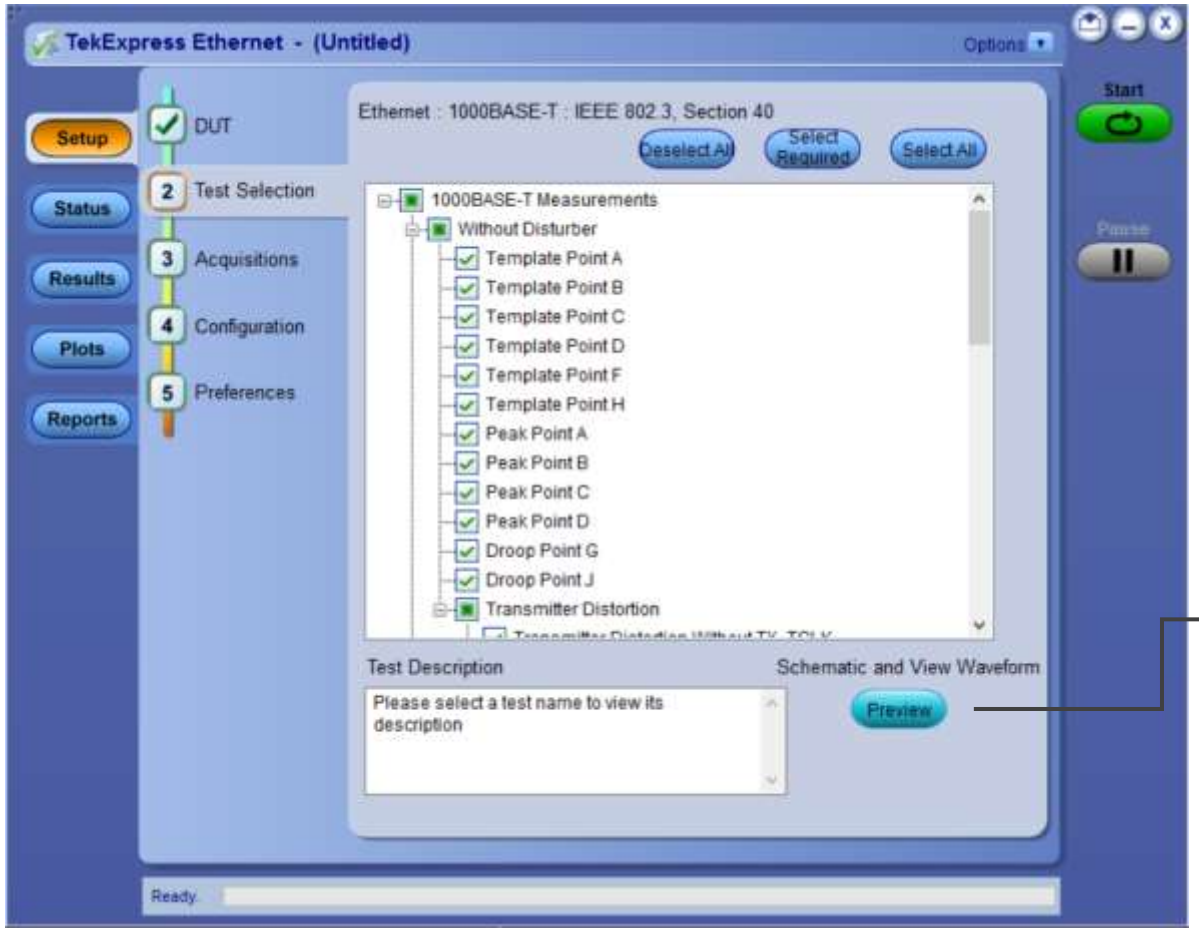
Panels

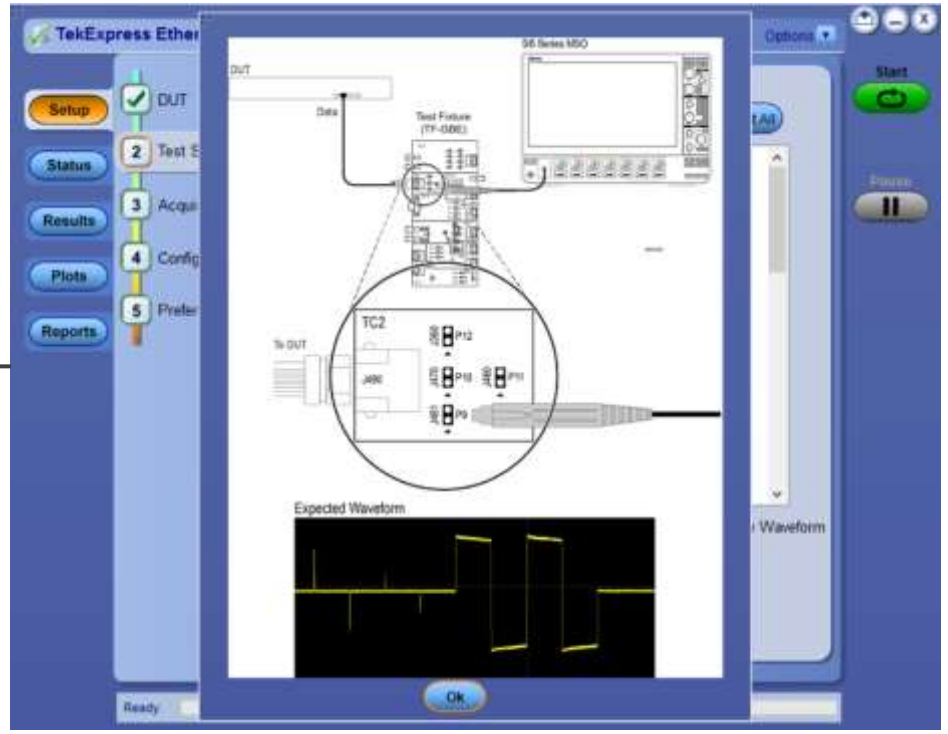
TEST SELECTION PANEL

This panels helps user to choose the tests.

The Preview button helps to show the schematic along with an image of the expected waveform.

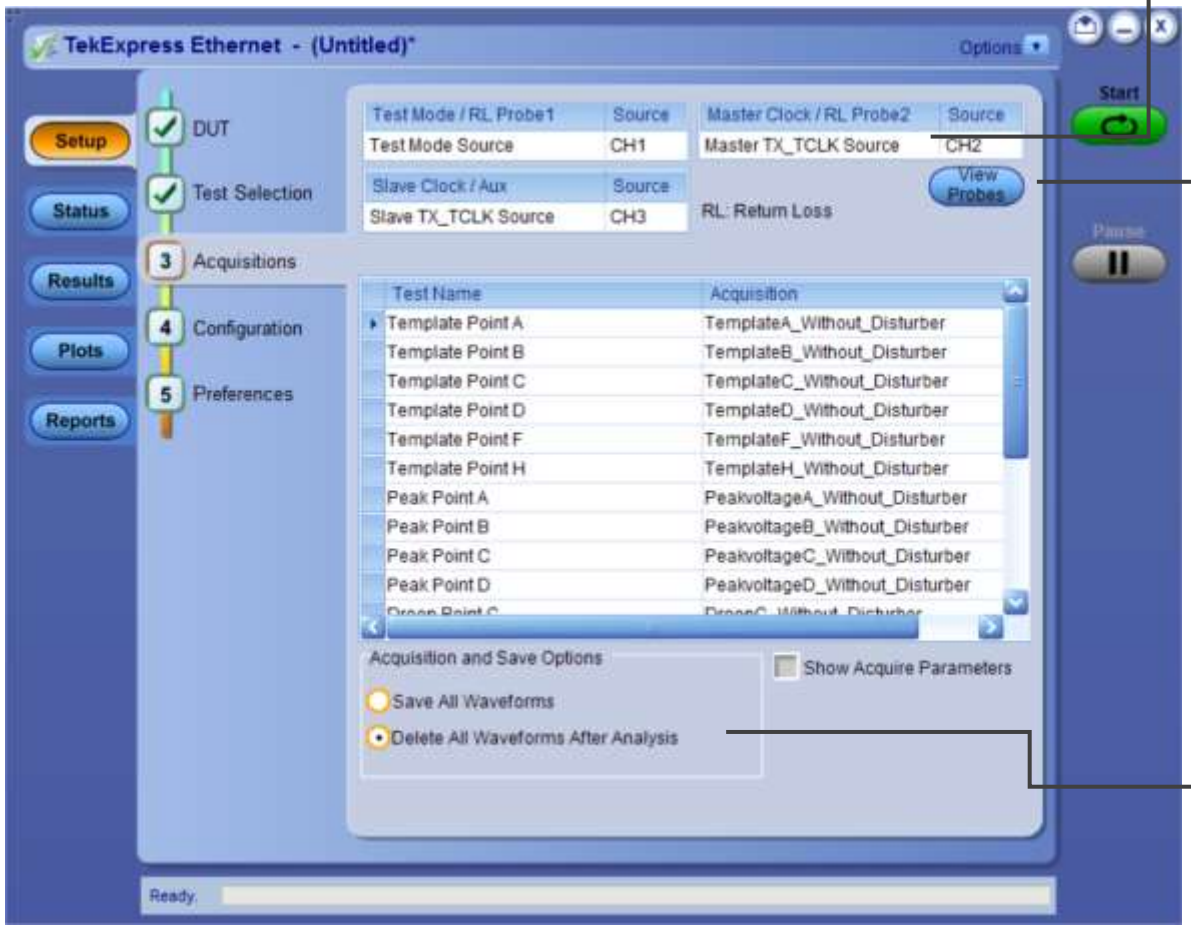
If the setup is connected correctly, the waveform displayed on the scope should match waveform displayed in the pop-up. Hence this button acts like a signal validation check even before running the tests





Panels

ACQUISITIONS PANEL



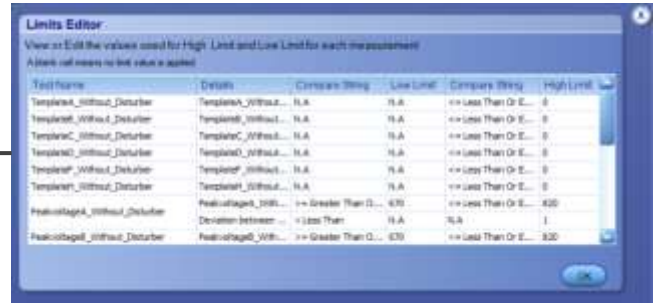
Shows the channel configuration

Shows the probe model information connected to the scope

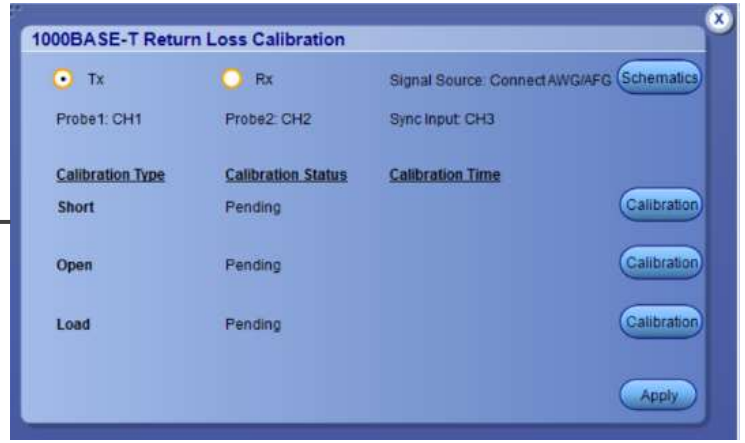
Choose this option to delete the acquired waveforms post analysis. This helps save memory on the hard drive.
Note: Waveforms will not be available for offline analysis if you enable this option

Panels

CONFIGURATION PANEL



Limits editor enables you to define the limits beyond compliance requirement and test the DUT for design margins



JigMatch calibrates the Disturber source as per the specification

Return Loss Calibration calibrates the Return Loss source as per the specification. This supports 'Short', 'Open' and 'Load' calibration

Panels

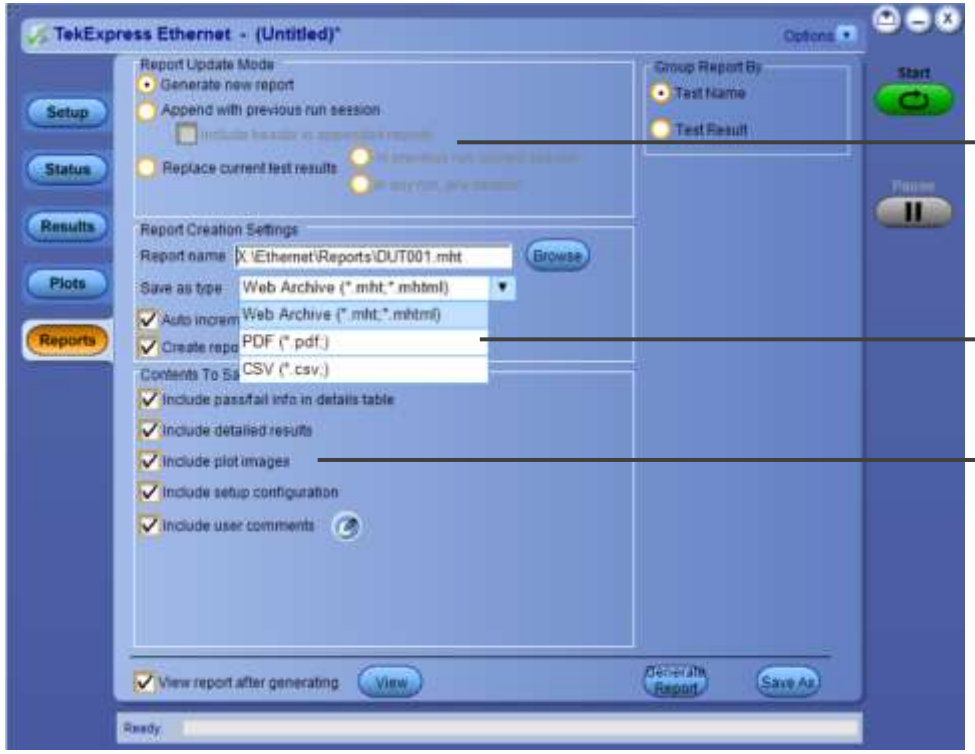
PREFERENCES PANEL

This option enables multiple test runs in a single execution. Use this option to check for repeatability of test results

This option enables auto-closing of the Warning and Error messages during the execution, so user need not have to spend time with the setup to click the action dialogue box

Panels

REPORTS PANEL

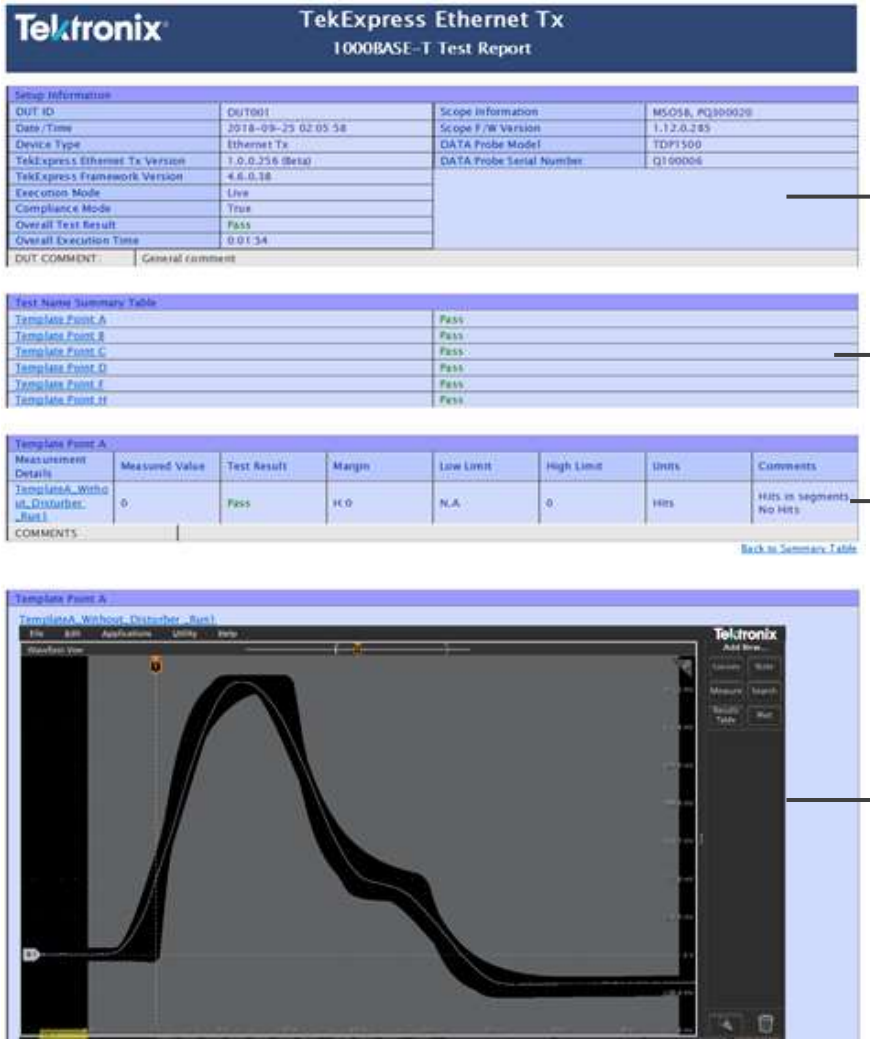


This option enables to append and replace the current test results in the report to any of the previous run reports

Multiple reporting formats are available. A report in CSV format helps user to create a custom report, by parsing the data from the CSV file

Choose what data you want included in the report file

Test Report



This section displays setup information like scope and probe models used, overall pass/fail result and test times

Test result summary indicates test and corresponding pass/fail results for a quick glance

Detailed results with test name, measured value, pass/fail limits and pass/fail status. Additional information related to the test appear under Comments section

Images corresponding to the test. This may contain waveform images, template/mask test images or plots like TIE or Return Loss plots

Probing

Probing in Ethernet Testing

- If the DC Offset introduced by the differential probe is not properly compensated, this error can quickly add up to large numbers when compared with the ±50 mV margin defined by the standards.
- Tektronix differential probes (TDP) have an AutoZero feature which automatically eliminates DC offset errors in the probe signal path.
- It is therefore very important to make the measurements after due signal path compensation on the oscilloscope and probe calibration.
- The interconnect path between the port and the probe should be as short as physically possible.

Summary

Ordering Information

- Scope : 5 or 6 Series MSO (>= 1GHz Bandwidth)
- Probe : 1x TDP1500/3500 or P6247/P6248 (2x if you perform Return Loss)
- Software : 5-CMENET/6-CMENET TekExpress Ethernet Compliance Solution
- Fixture : TF-GBE-BTP

Tektronix

10BASE-T1S

Validation and Compliance Testing

1 MARCH 2021

Trends Shaping the Car Industry

A revolution driven by autonomy, connectivity, electrification, and sharing

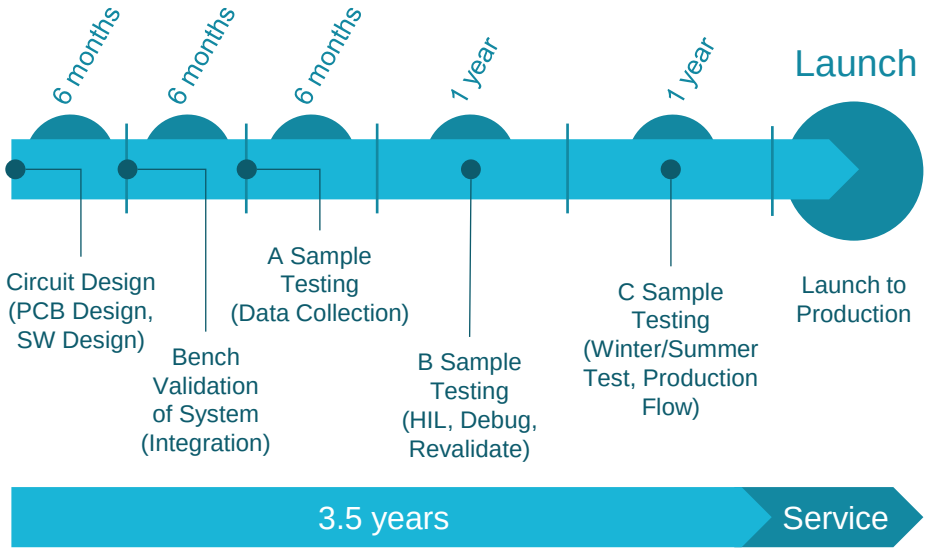
A Autonomy requires the use of better sensors

C Connectivity enables new forms of vehicle communication

E Electrification requires new powertrain technologies

S Shared mobility creates new standards and testing

Validation Workflow



Electronics is performing critical functions.

The validation methods *(and challenges)* are different now.

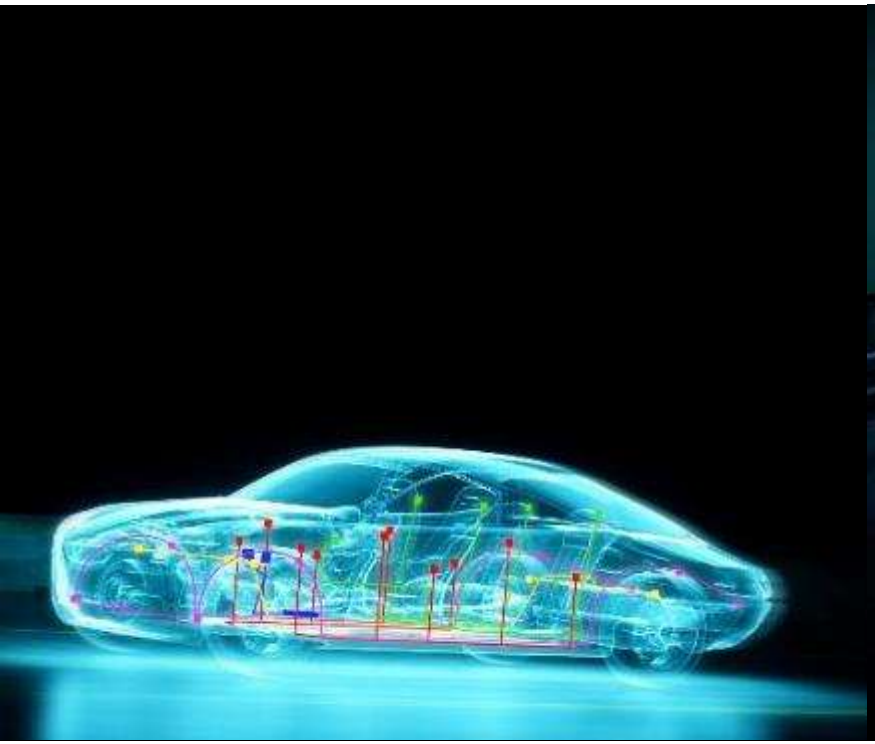
Challenges

- Liability
- Traceability
- Long Testing Cycles
- Increasing Complexity
- Security
- Huge Amounts of data
- Software Modelling
- Calibration
- Portability

T&M tasks and challenges

• Portability Across Platform • Traceability	• Certificates • Hardware in Loop	• On Road Testing • Data Retention	• Software Modelling • EMI/EMC

Automotive Focus Areas

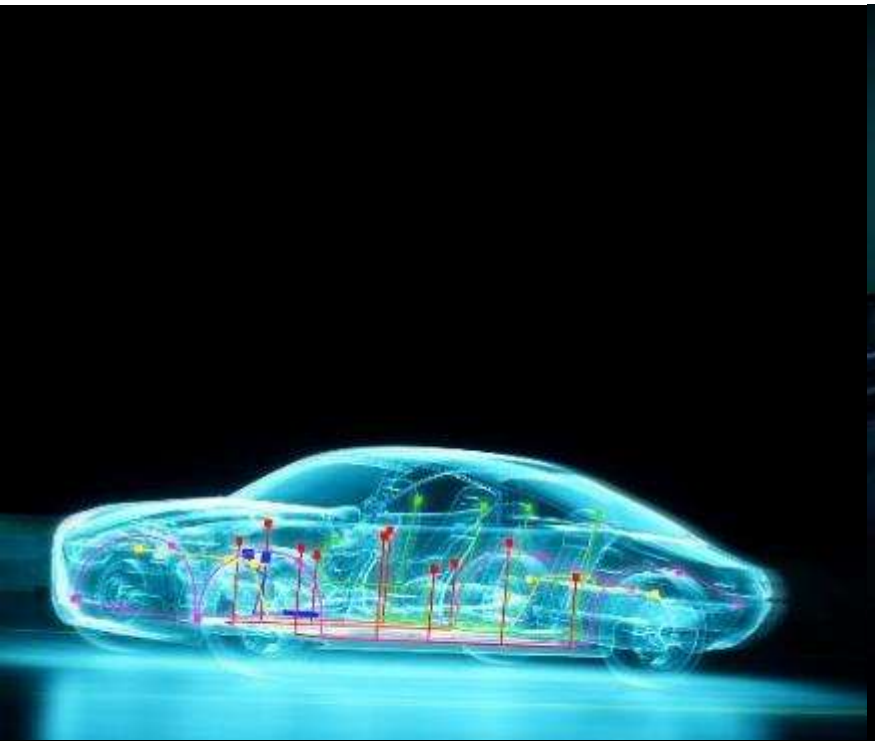


In-Vehicle Networking

Vehicle Sensors

Powertrain & Electrification

Automotive Focus Areas



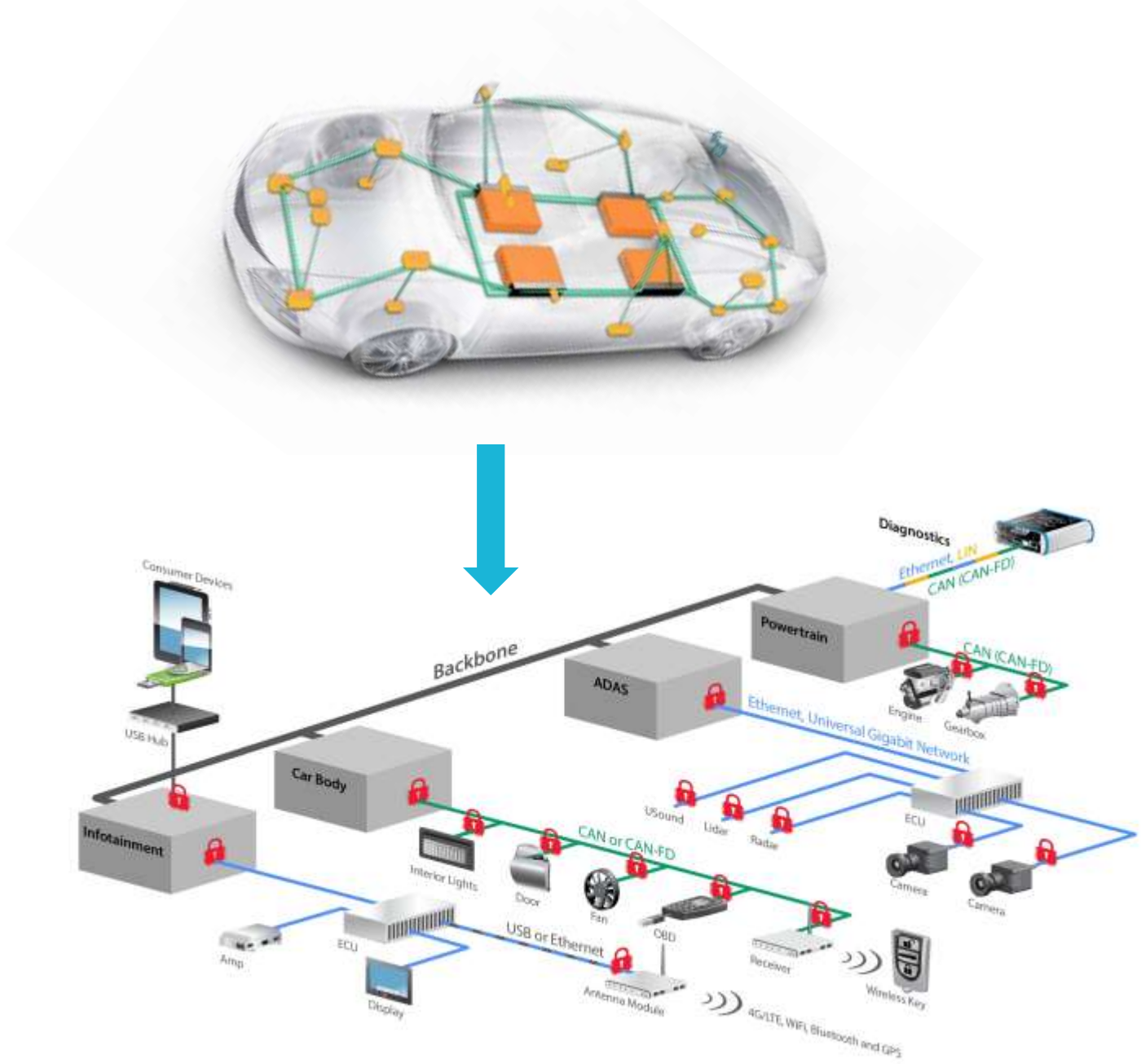
In-Vehicle Networking

Vehicle Sensors

Powertrain & Electrification

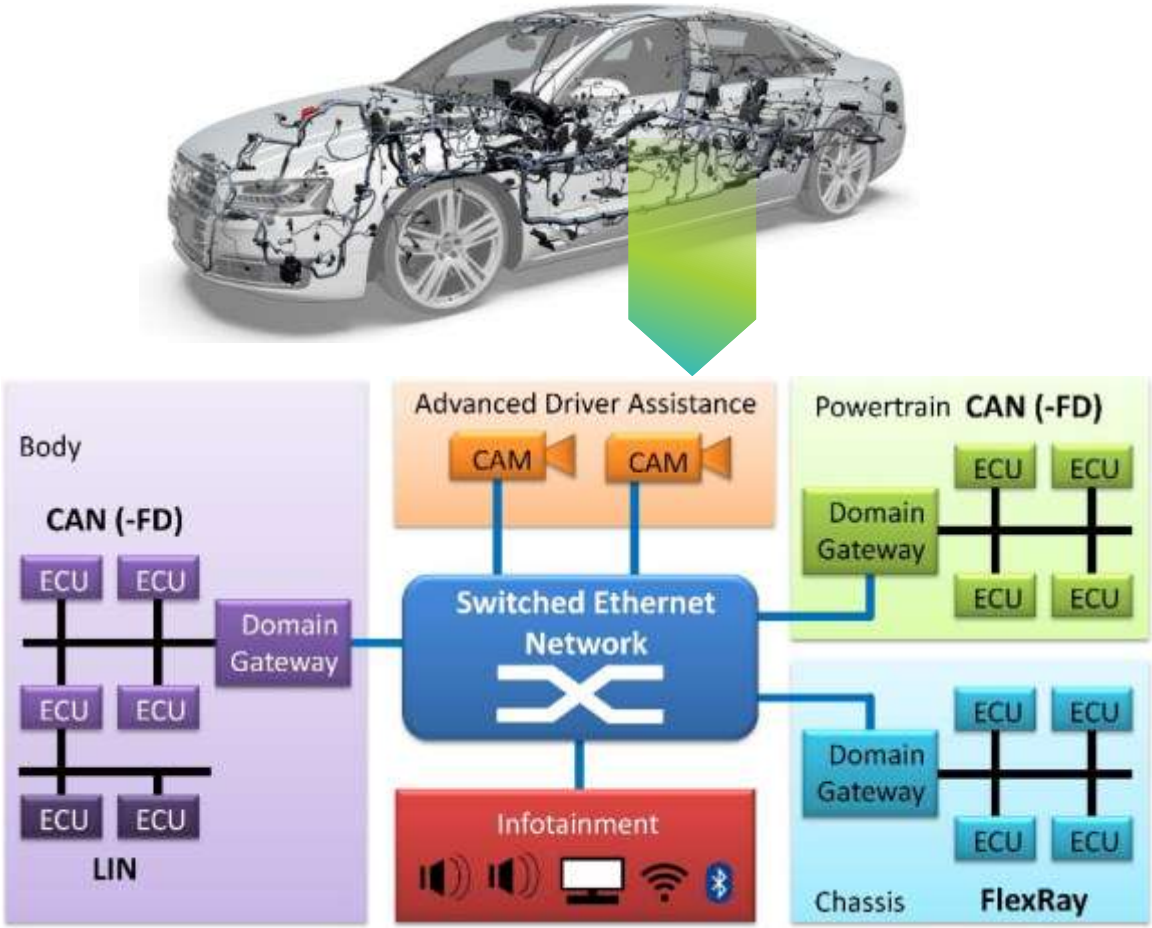
What is IVN?

- Electronics inside the car communicate with each other over In-Vehicle-Network.
- IVN wiring is the 3rd largest contributors of overall weight of car and 2nd largest contributors of overall BOM
- IVN requirement:
  - Reliable data transfer at Automotive harsh environment
  - EMI/EMC
  - Low weight, low cost, low power



In-Vehicle Networking

DOMAIN ARCHITECTURE



Source: Dr. Kai Richter and Jonas Diemer of Symtavision and Daniel Thiele, Philip Axer and Dr. Rolf Ernst of Technische Universität Braunschweig

In-Vehicle Network standards

Simplistically

CAN – The standard

LIN – Interior Lights / Windows

SENT – Measurements

Ethernet – The emerging standard

Automotive Electronics Application Technologies				
DATARATE	SAFETY	INFOTAINMENT-TELEMATICS	POWERTRAIN	BODY ELECTRONICS
Sensor 25-400kbps	DSI3 (airbag) PSI5 (airbag)		SENT	
Low speed Control 20kbps	LIN, CXPI			LIN, CXPI
Multi-master Control	CAN, CAN-FD, 10BASE-T1S	CAN, CAN-FD, 10BASE-T1S	CAN, CAN-FD	CAN, CAN-FD
Safety Critical	FlexRay/10BASE-T1S		FlexRay/10BASE-T1S	
Connectivity >100Mbps	100/1000BASE-T1, LVDS, NGBASE-T1	100/1000BASE-T1,GVIF, GMSL, HDBaseT, LVDS	100/1000BASE-T1	

90% of communication in car is below 10Mbps

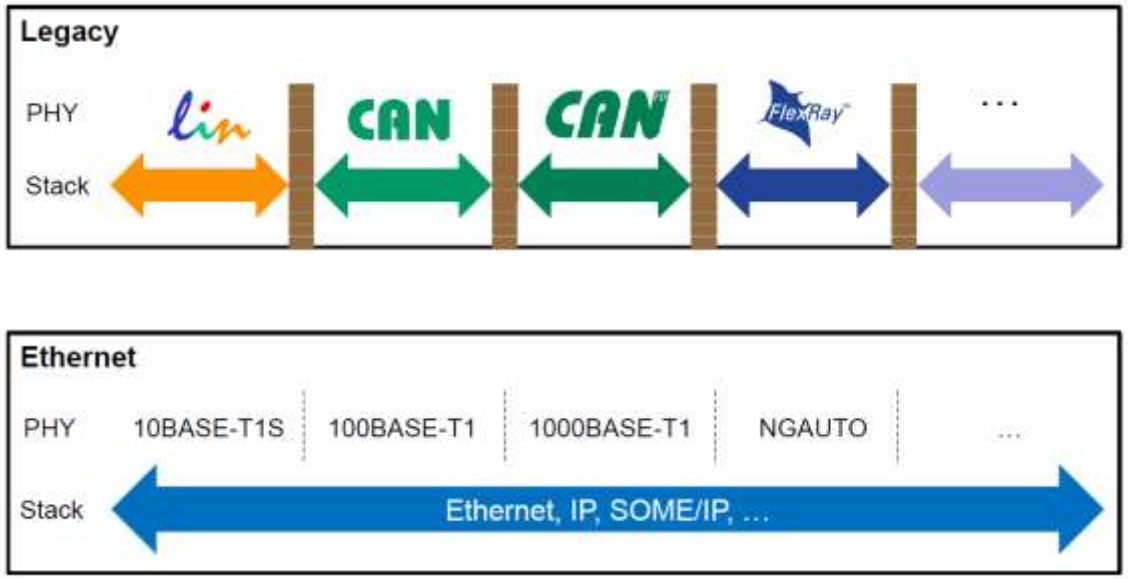
Low speed Applications

- Hands-free microphones
- Active speakers
- Noise vibration harshness
- Parking ECU
  - Radar
  - Ultrasonic
- Engine ECU
- Body ECU
- Active suspension
- Steering/braking system
- Charging units for electric cars
- Traffic sign recognition

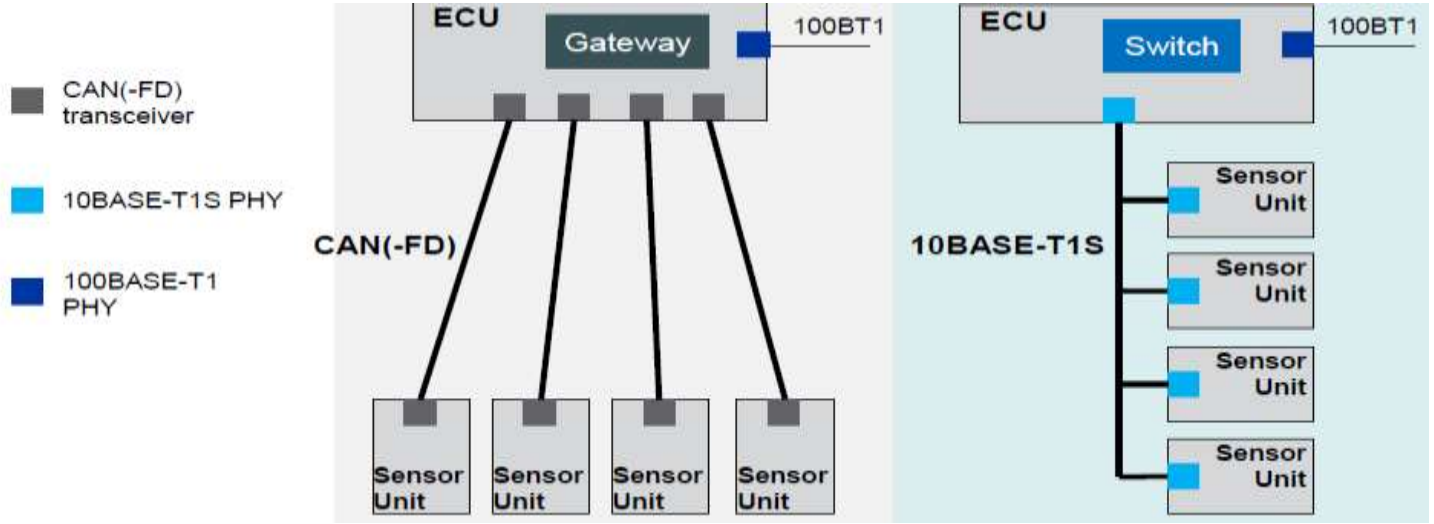
Automotive Ethernet Standard

- **Standards:** 10BASE-T1S (802.3cg), 100BASE-T1 (802.3bw), 1000BASE-T1 (802.3bp) and Multigigabit Ethernet (802.3ch, In progress)
- Common Architecture with multiple speed option
- Unshielded cable, Full-duplex cable reduces cost by 80% and cable weight upto 30%
- Simplified Architecture

OSI	Automotive Ethernet
7 Application	Applications (HTTP, FTP, SMTP..)
6 Presentation	
5 Session	
4 Transport	TCP
3 Network	IP
2 Data Link	Network Access
1 Physical	10/100/1000/NGBASE-T1



Why 10Mbps Automotive Ethernet?

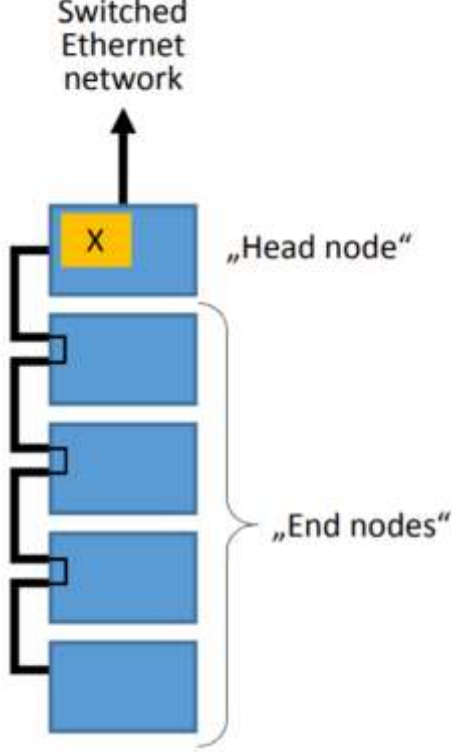


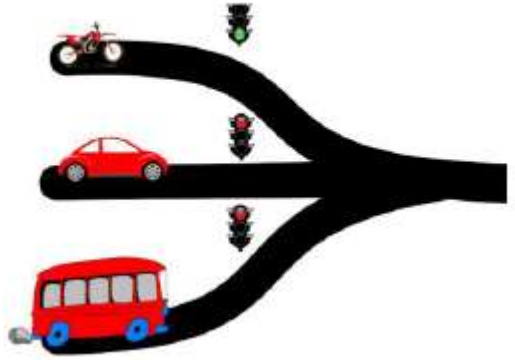
	CAN-FD	10BASE-T1S	Advantage
#PHYs	8	5	Fewer PHY required
#connectors @ECU	4	1	Less connector on ECU, less space
#Cable	4	1 Bus line	Less cabling, Extendibility, Scalability
Bandwidth	4 * 2Mbps	10Mbps	More bandwidth
Ethernet based network	No	Yes	Seamless integration into overall Ethernet system
Gateway	Yes	No	Eliminate need to translate message

Source: Microchip AEC,2019 presentation

10BASE-T1S overview

- IEEE 802.3cg specification
- Single pair cables, Multidrop bus topology or Point to Point
  - At least 8 nodes, 25m, 24 AWG cable
- Designed to meet Automotive EMC/EMI requirement
  - BER < 10^-10
- Physical Layer collision avoidance (PLCA)
  - CSMA/CD enhancement that dynamically creates transmit opportunities
  - Adaptive: bounded latencies, efficient BW allocation, fair
- Optional Power over Data line (PoDL) support



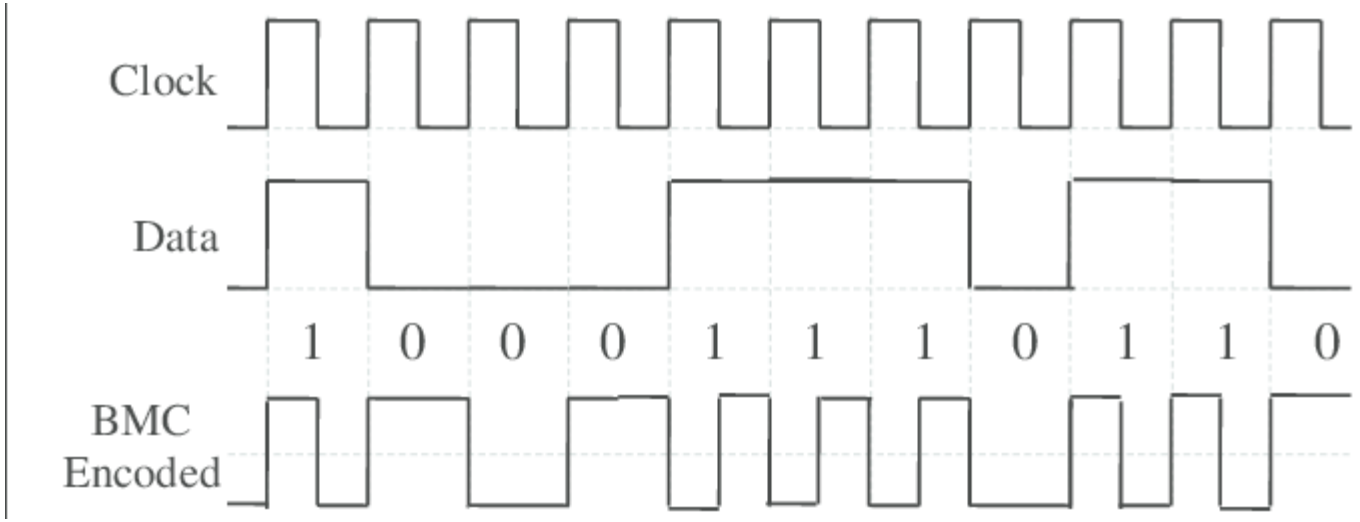


10BASE-T1S overview

	10BASE-T1S	100BASE-T1	1000BASE-T1	NGBASE-T1
Datarate	10Mbps	100Mbps	1Gbps	2.5/5/10Gbps
Symbol rate	12.5MHz	66.66MHz	750MHz	1.4/2.8/5.6 GHz
Line coding	4B/5B, Differential Manchester Encoding	PAM3	PAM3	PAM4
Voltage	1Vpp	2.2Vpp	1.3Vpp	1.3Vpp
Communication	Half Duplex	Full Duplex	Full Duplex	Full Duplex
Configuration	Point to Point Multidrop	Point to Point	Point to Point	Point to Point
Cable length	15m/25m	15m	15m	15m

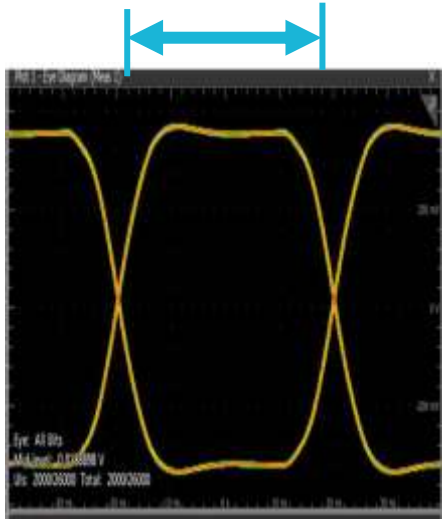
10BASE-T1S Encoding

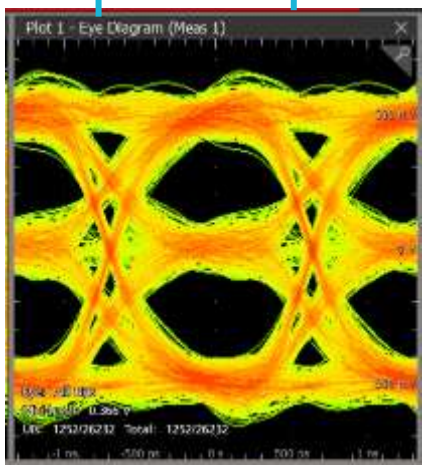
- 4B/5B, Differential Manchester Encoding

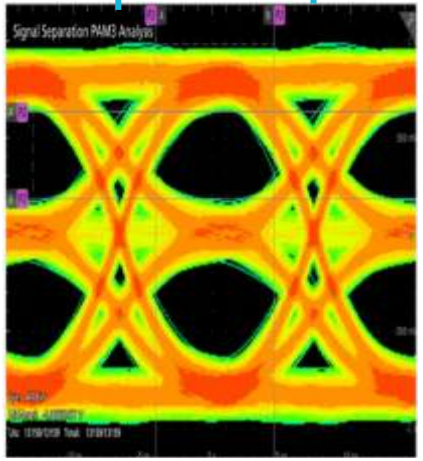


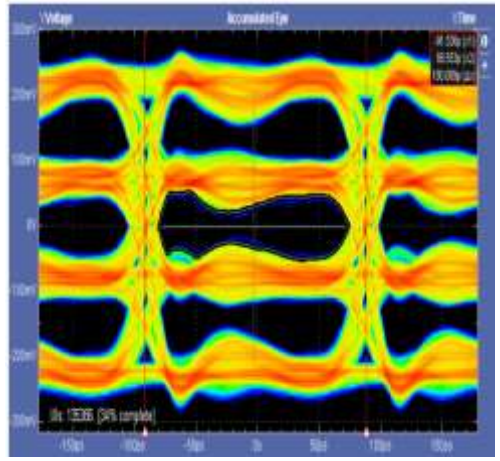
Automotive Ethernet standards

10BASE-T1S 10Mbps 12.5MHz	100BASE-T1 100Mbps 66.66MHz	1000BASE-T1 1Gbps 750MHz	Multigigabit 2.5/5/10Gbps 1.4/2.8/5.6GHz
40ns	15ns	1.33ns	0.714/0.357/0.179ns









Automotive Ethernet summary

	10BASE-T1S	100BASE-T1	1000BASE-T1	Multigigabit
Datarate	10Mbps	100Mbps	1Gbps	2.5/5/10Gbps
Symbol rate	12.5MHz	66.66MHz	750MHz	1.4/2.8/5.6 GHz
Line coding	4B/5B, Differential Manchester Encoding (DME)	PAM3	PAM3	PAM4
Voltage	1Vpp	2.2Vpp	1.3Vpp	1.3Vpp
Communication	Half Duplex or Full Duplex	Full Duplex	Full Duplex	Full Duplex
Configuration	Point to Point Multidrop	Point to Point	Point to Point	Point to Point
Cable length	15m/25m	15m	15m	15m
Cable Type	24-26 AWG	Unshielded twisted pair	Unshielded twisted pair	Shielded twisted pair
Application	Audio, Parking ECU, Engine ECU, Body ECU, Active suspension, Steering/braking system, Charging units for electric cars	Infotainment, Driver Assistance systems	Infotainment, Driver Assistance systems	Infotainment, Driver Assistance systems, ECU to ECU communication

Automotive Ethernet

Test Requirement

Automotive Ethernet Compliance

100BASE-T1	1000BASE-T1	10BASE-T1S	NGBASE-T1
PHY and Protocol IEEE 802.3bw	PHY and Protocol IEEE 802.3bp	PHY and Protocol IEEE 802.3cg	PHY and Protocol IEEE 802.3ch (In Progress)
Open Alliance TC1	Open Alliance TC12	Open Alliance: In Progress	Open Alliance: In Progress

TC8 ECU Specification

Automotive Ethernet compliance

Test Name	10BASE-T1S*	100BASE-T1*	1000BASE-T1*
Transmitter output Droop	147.5.4.2	96.5.4.1	97.5.3.1
Transmitter distortion	NA	96.5.4.2	97.5.3.2
Transmitter Timing Jitter (Master/Slave)	147.5.4.3	96.5.4.3/ 96.5.4.5	97.5.3.3
Transmitter Power Spectral Density (PSD)	147.5.4.4	96.5.4.4	97.5.3.4
Transmitter Clock Frequency	NA	96.5.4.5	97.5.3.6
Transmitter Peak Differential Output	147.5.4.1	96.5.6	97.5.3.5
MDI Return Loss	146.8.3	96.8.2.1	97.7.2.1
Transmitter MDI Timing Jitter	NA	NA	97.5.3.3
MDI Mode conversion Measurement	Not defined		
Common Mode Emission Test	Not defined		

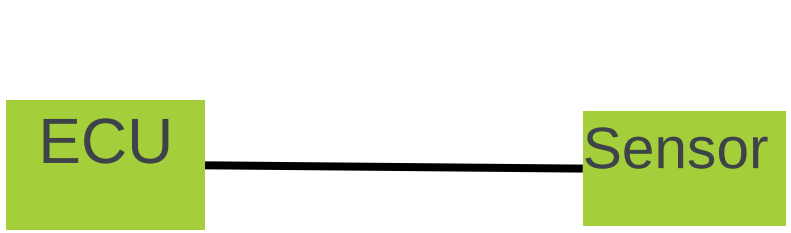
*IEEE spec ref number

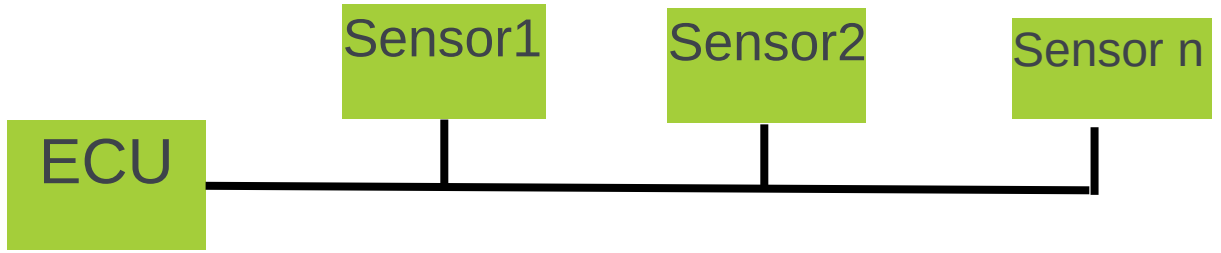
10BASE-T1S PMA Test Specification

- PHY Media Attachment Compliance Test
- PHY test mode configuration should be provided by PHY vendor
- Transceiver PHY electrical test requirements include:
  - Maximum Output Droop
  - Timing Jitter
  - Power Spectral Density
  - Clock Frequency
  - Peak Differential Output
  - MDI Return Loss
- Operating mode: Point to Point or Multidrop

Test Name	Test Mode
Transmitter Output Droop	2
Transmitter Timing Jitter	1
Transmitter Power Spectral Density (PSD)	3
Transmitter Clock Frequency	1
Peak Differential Output	1
MDI Return Loss	4

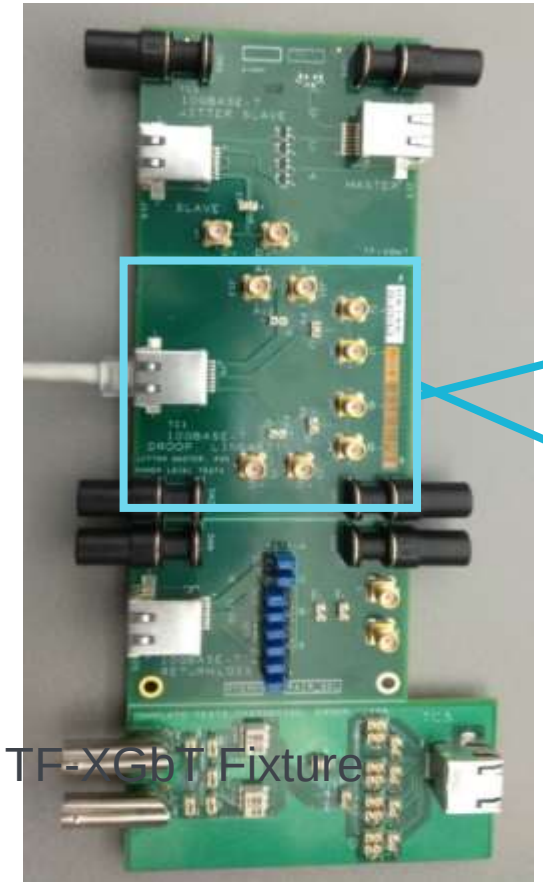
Mode of operation





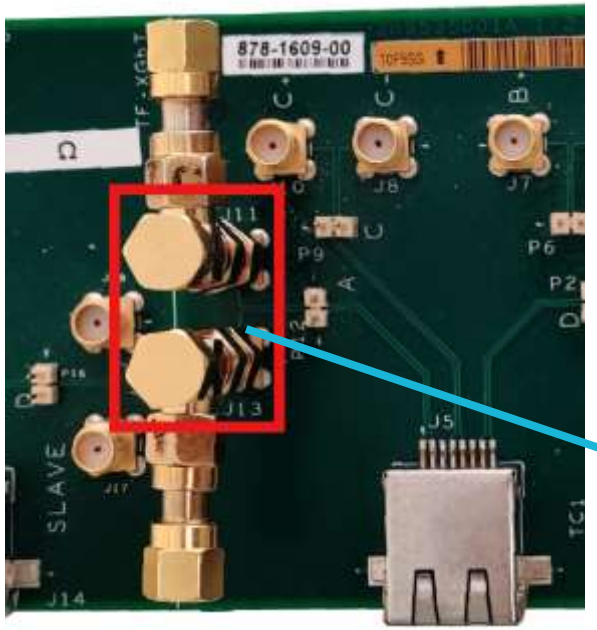
	Point to Point	Multidrop
Node	1 node	Upto 8 node, with 25cm stub
Cable length	15m reach	25m reach
Transmission load	100 ohm	50 ohm

Signal Access



TF-XGbT Fixture

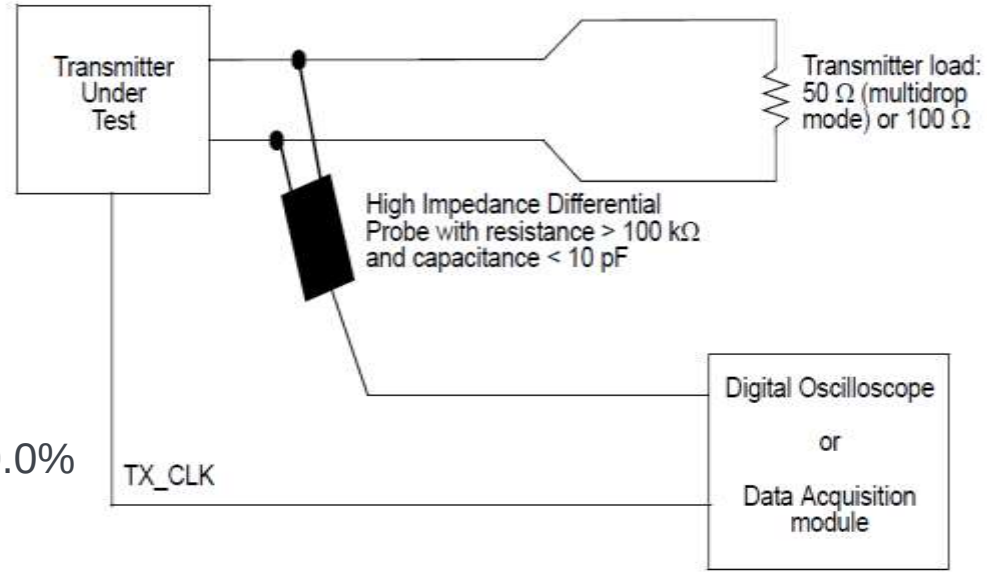
Point to Point test config (100ohm)

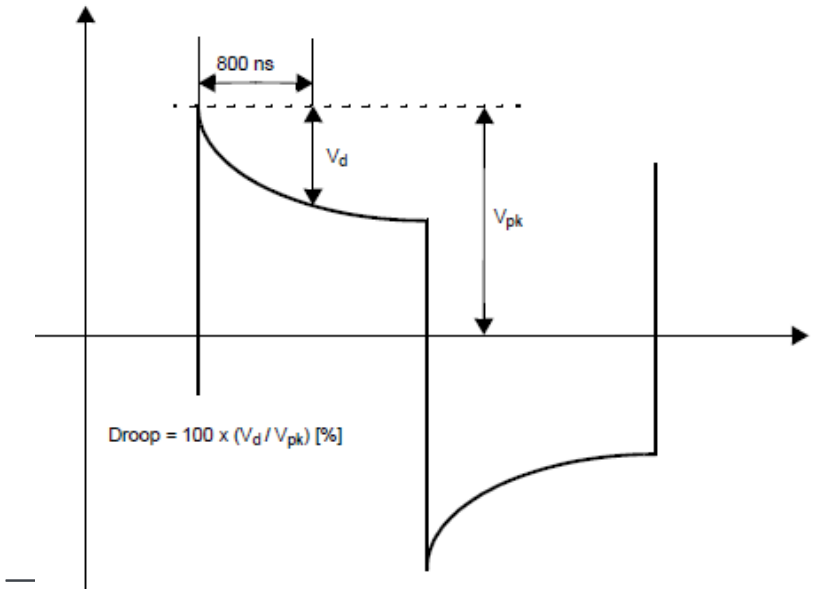


Multidrop test config (50 ohm)

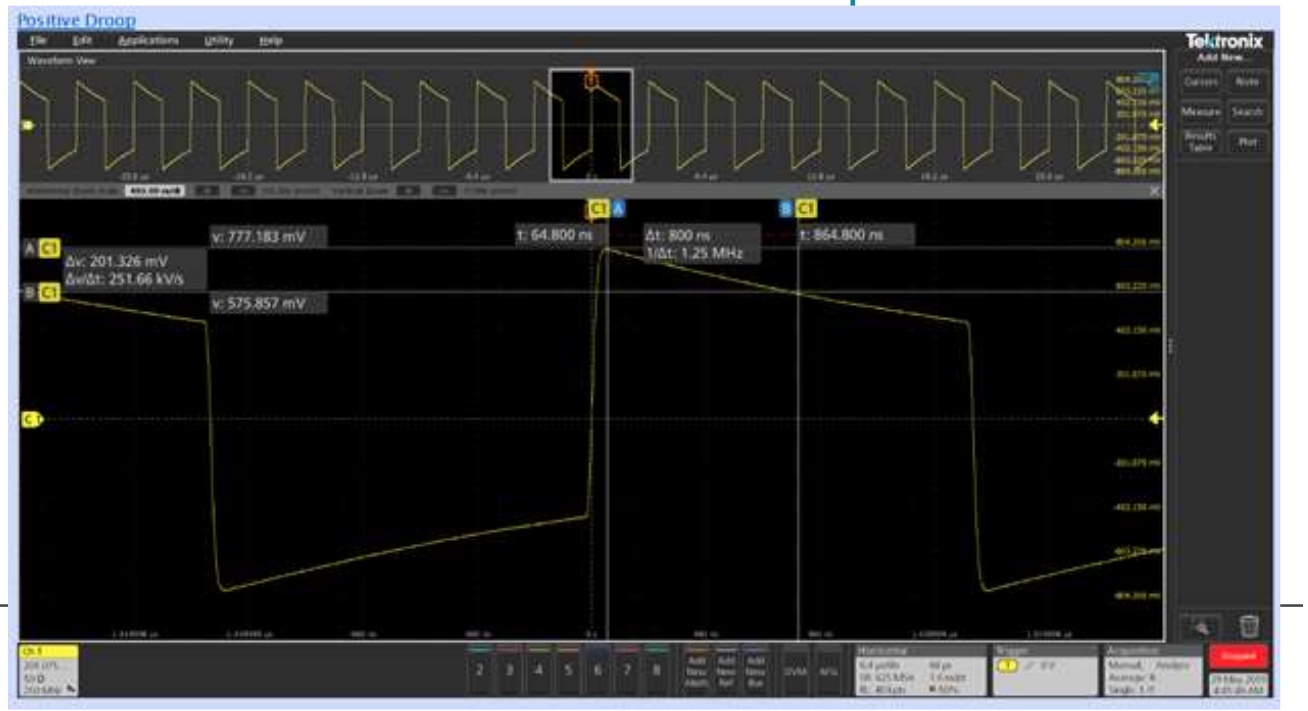
Maximum Droop Test

- Droop Measurement
  - Configure Test Mode 2
  - Transmit fifteen {+1} symbols followed by fifteen {–1} symbols continually
  - Value of 10 bit time pulse after initial peak, shall be less than 30.0%
  - Calculate Vpk and Vdelay as shown below
  - Vd= Vpk-Vdelay
  - Droop= 100 x (Vd/Vpk)%



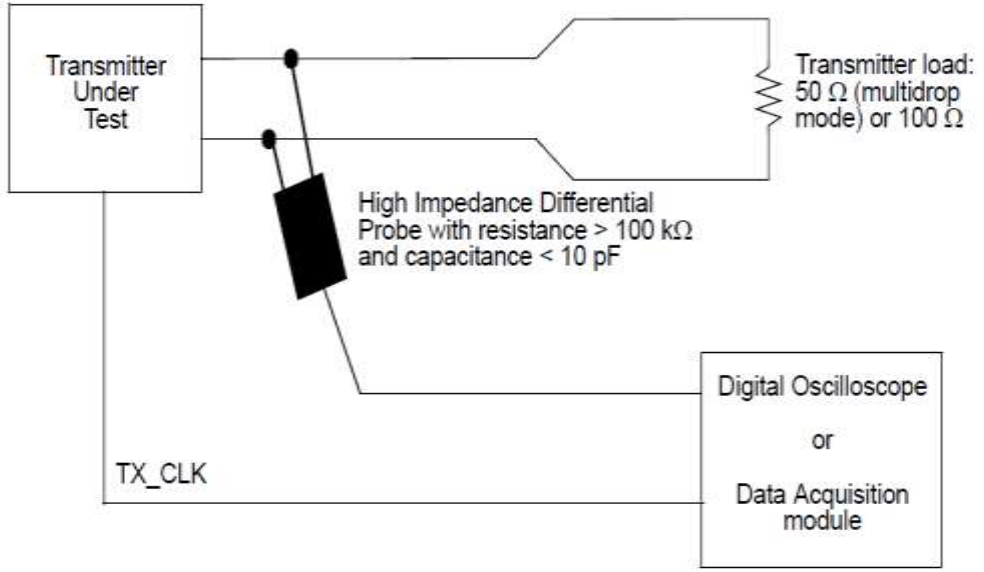


Droop

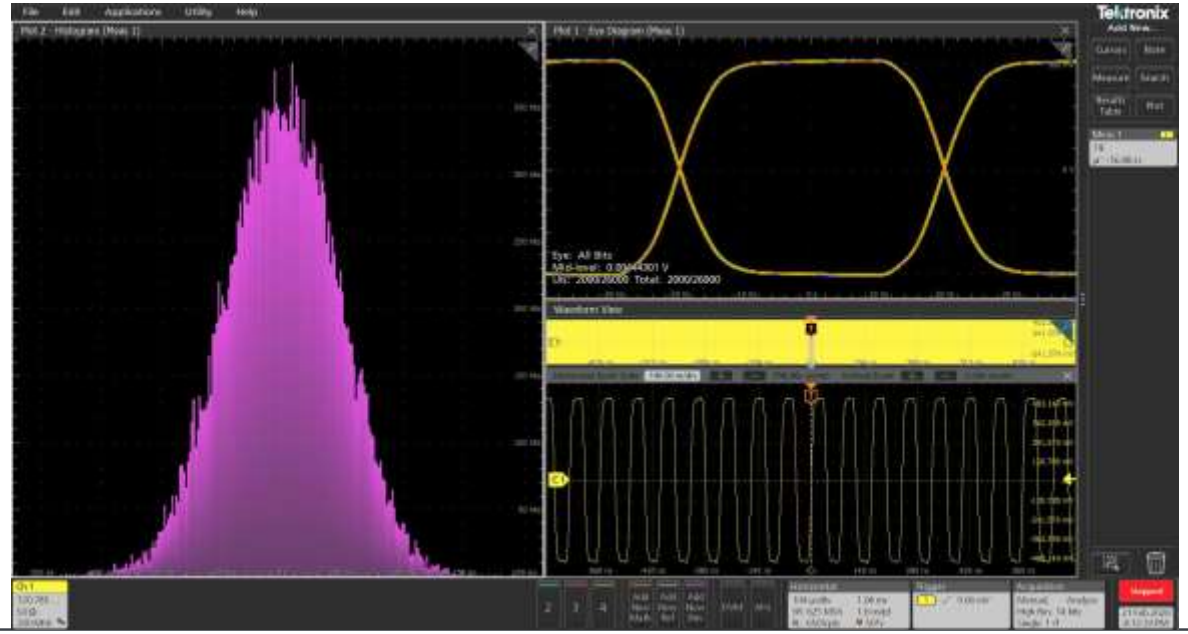


Clock Frequency and Jitter Tests

- Clock Frequency Measurement
  - Configure Test Mode 1
  - This is informative test
- Timing Jitter Measurement
  - Transmitter clock measurement
  - PHY output jitter shall be less than 5 ns (symbol to symbol)

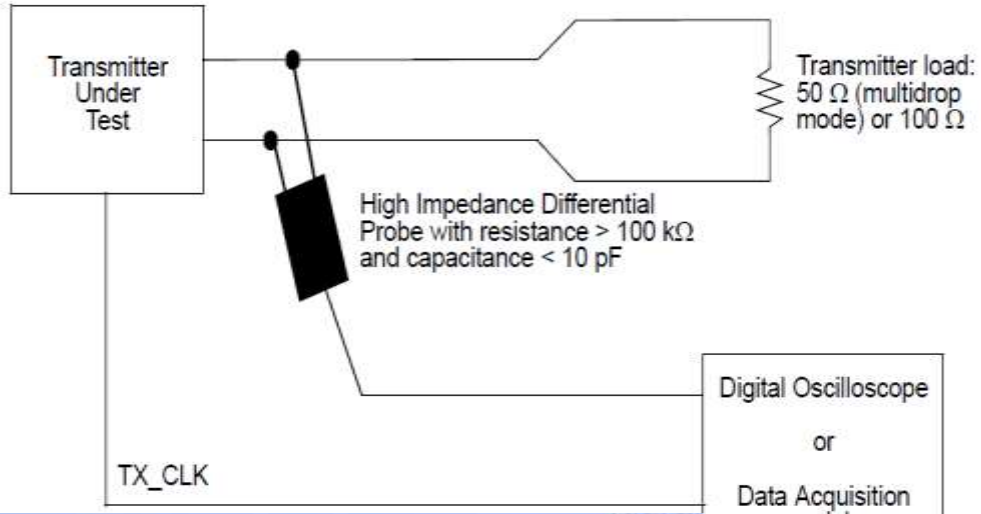


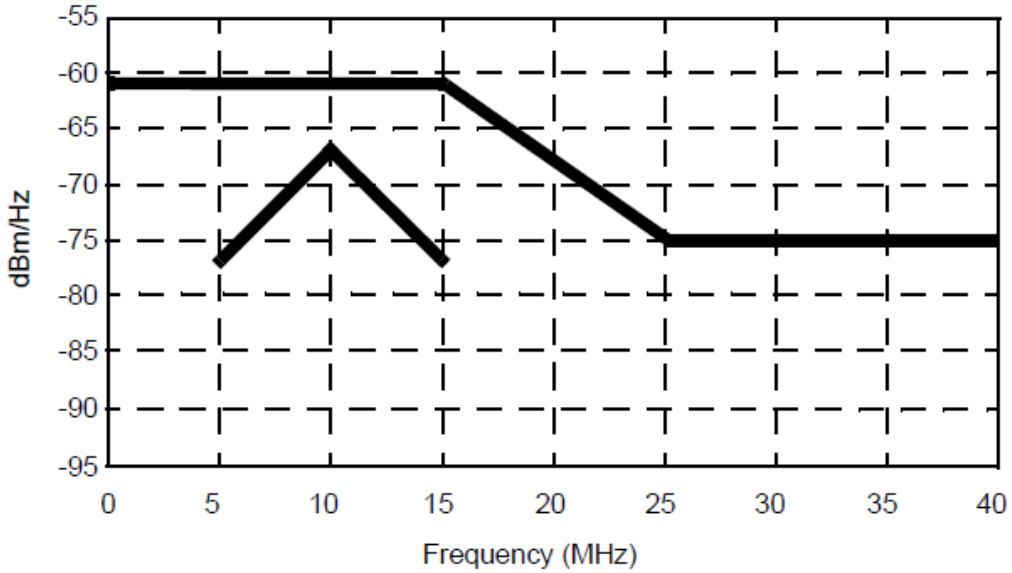
Clock Frequency & Jitter



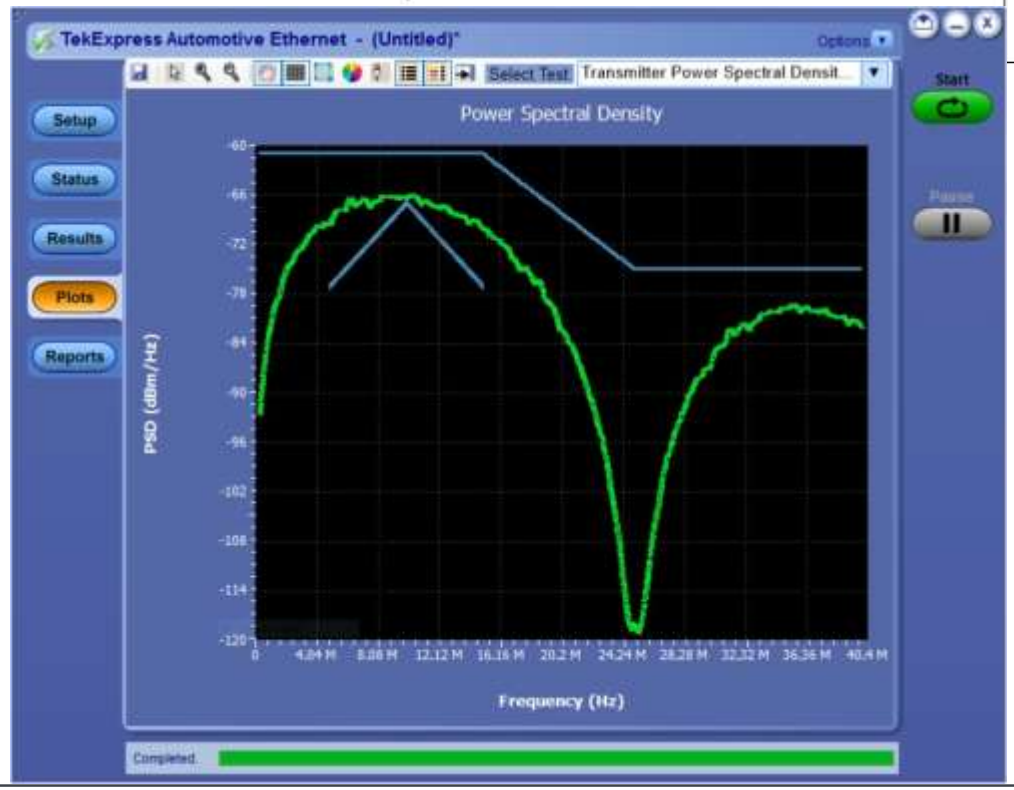
Power Spectral Density

- Power Spectral Density
  - Configure Test Mode 3
  - Compliance test spec allows use of scope or spectrum analyzer



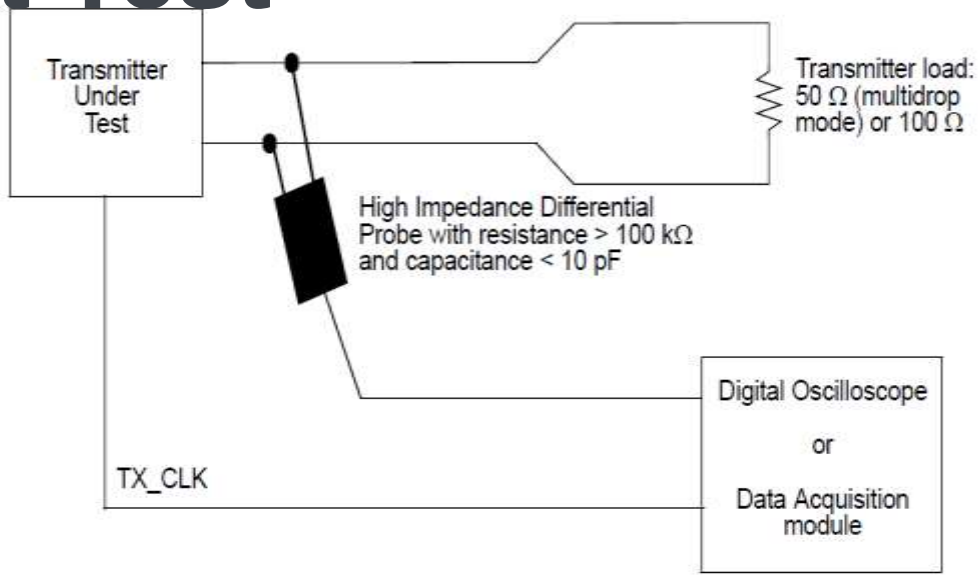


PSD Mask

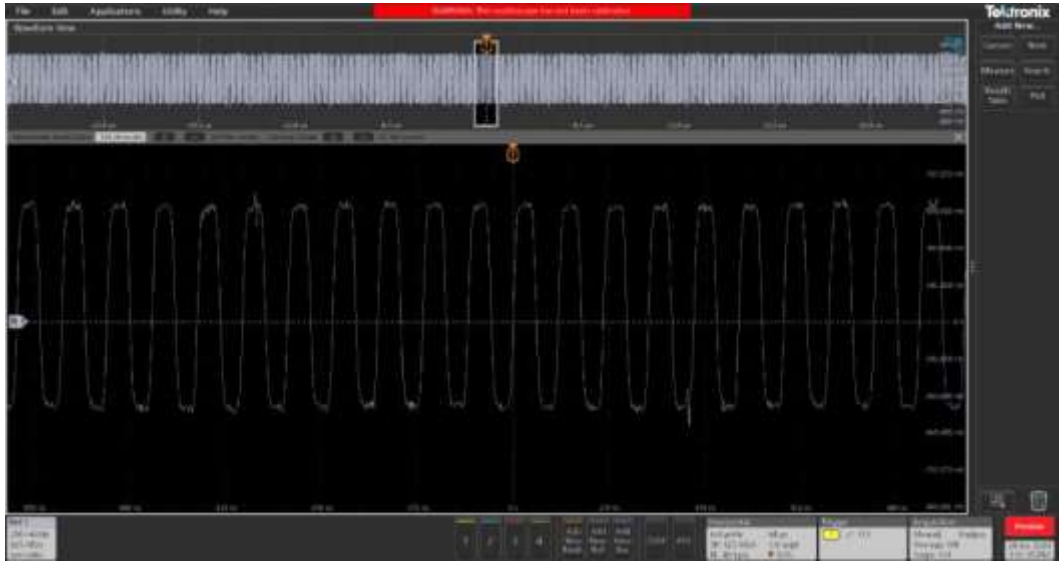


Tx Peak Differential Output Test

- Peak Differential Output Test
  - Configure device in Test mode 1
  - Peak-to-peak differential amplitude shall be 1 Vpk-pk ± 20 %

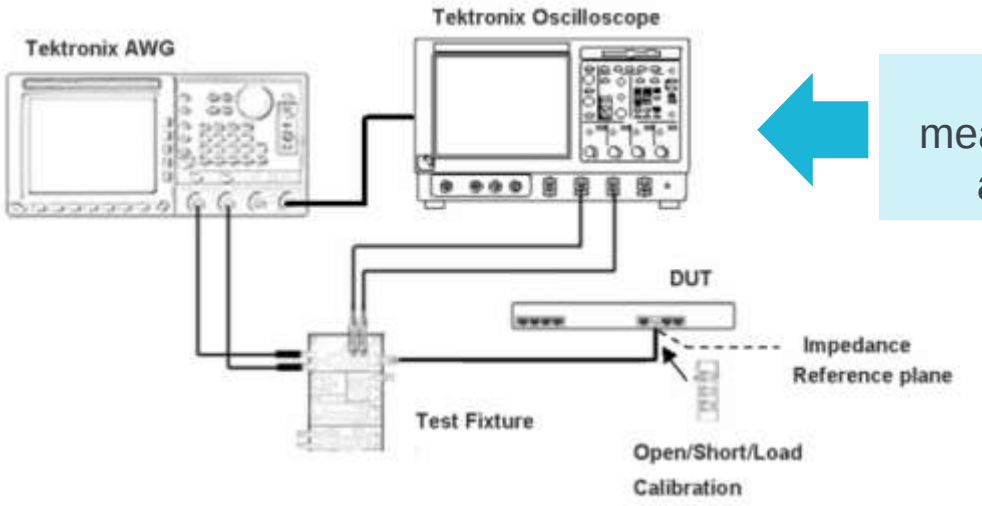


Differential Output



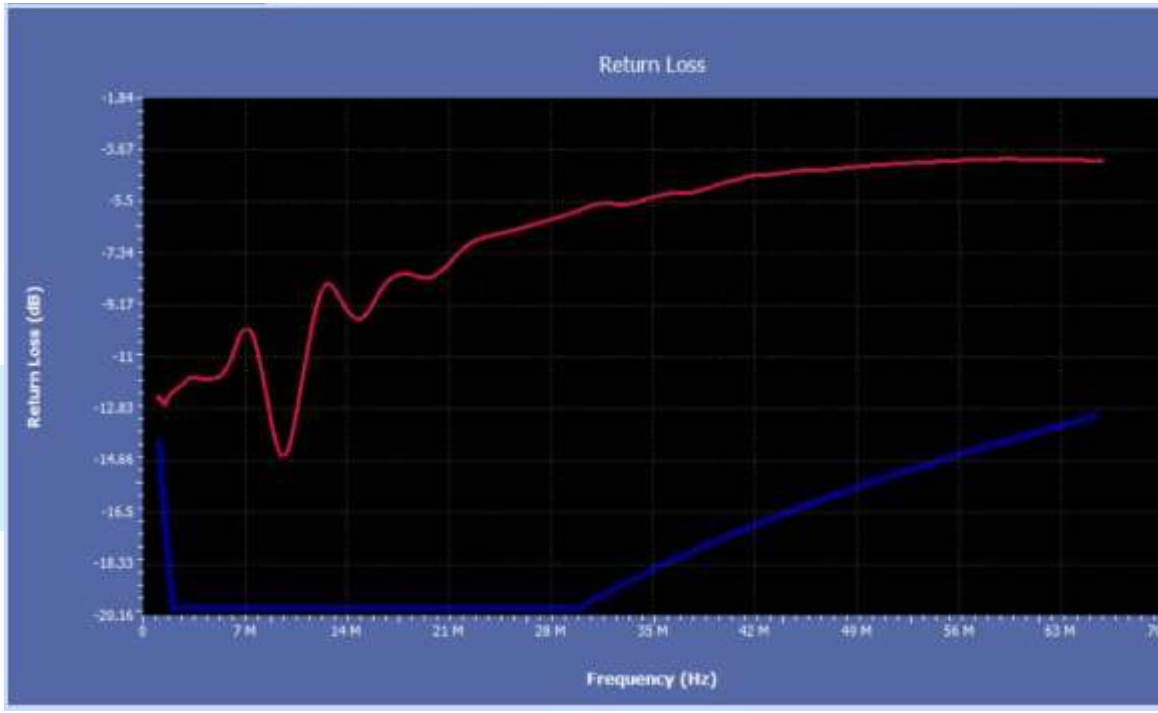
MDI (connector) Return Loss Test

- Return Loss Measurement
  - Measurement is focused on the connector and not the link (cable) return loss
  - Tektronix Patented approach of Scope based Return loss measurement reduces cost of testing
  - Correlated measurement with VNA



Similar measurement as VNA

Return Loss using scope



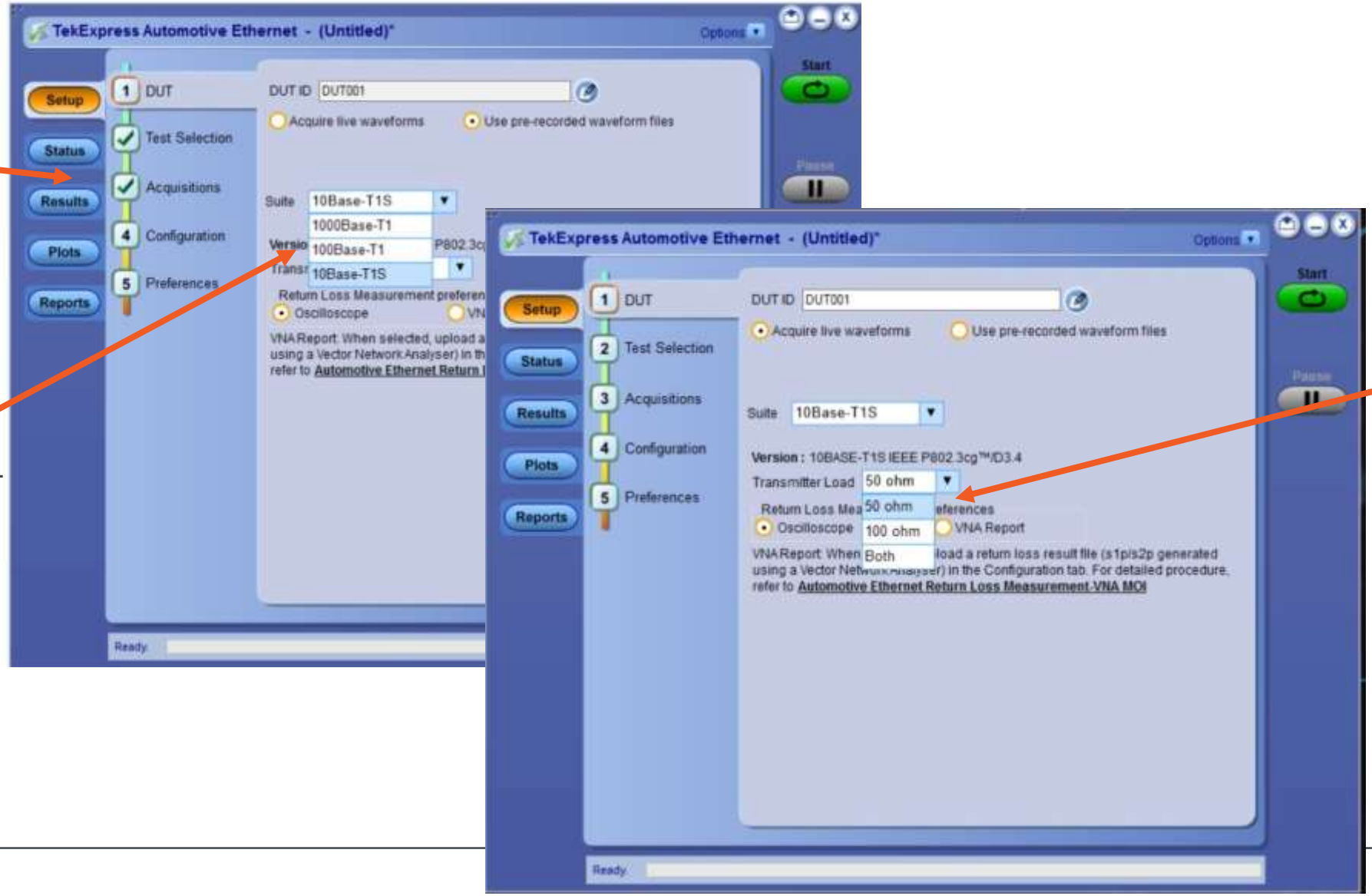
10BASE-T1S Test solution

Automated Compliance

Wizard-based automation

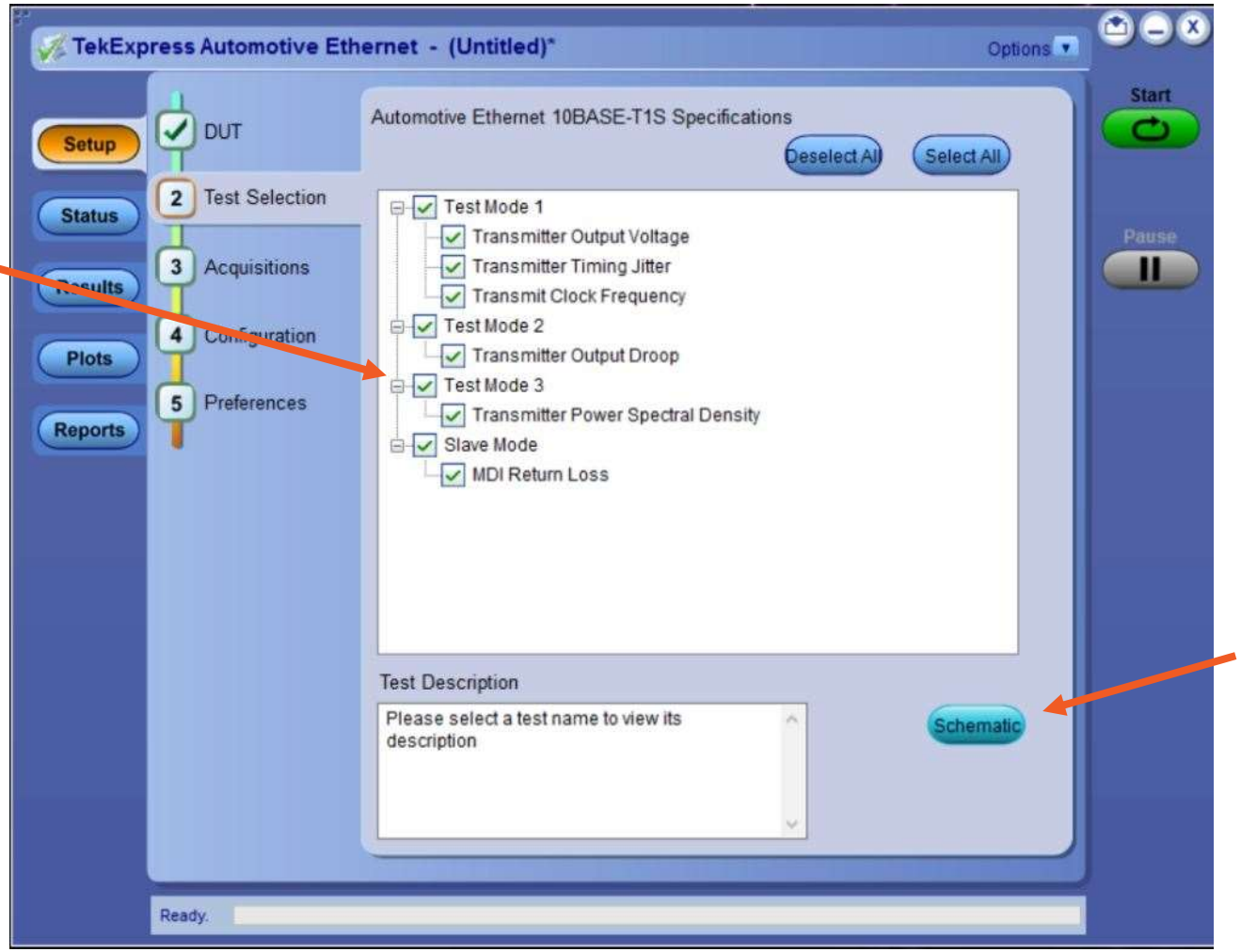
10/100/1000BASE-T1

Point to Point or Multidrop



Test Selection

Select multiple tests



Test description with connection diagram

Automated Report Generation

Report with Pass/Fail, Margin and Plots

Tektronix® TekExpress Automotive Ethernet
Transmitter Test Report

Setup Information			
DUT ID	DUT001	TekExpress Automotive-Ethernet	1.3.0.95
Date/Time	2020-01-28 12:59:09	Framework Version	4.15.0.2
Pre-Recorded Mode	False	Scope Model	MSO54
Compliance Mode	True	Firmware Version	1.14.13.6144
Suite Name	10Base-T1S	Probe1 Model	TDP1500
Overall Execution Time	0:00:31	Probe1 Serial Number	Q100012
Overall Test Result	Pass	Probe2 Model	TCA-SMA
		Probe2 Serial Number	N.A
DUT COMMENT:	General Comment - Automotive Ethernet DUT		

Test Name Summary Table	
Transmitter Output Droop	Pass

Statistics						
Measurement Details	Run Count	Min	Max	Average	Units	Standard Deviation
Positive Output Droop_50ohm	5	3.245	3.47	3.3828	%	0.0934
Negative Output Droop_50ohm	5	3.219	3.809	3.6254	%	0.2297

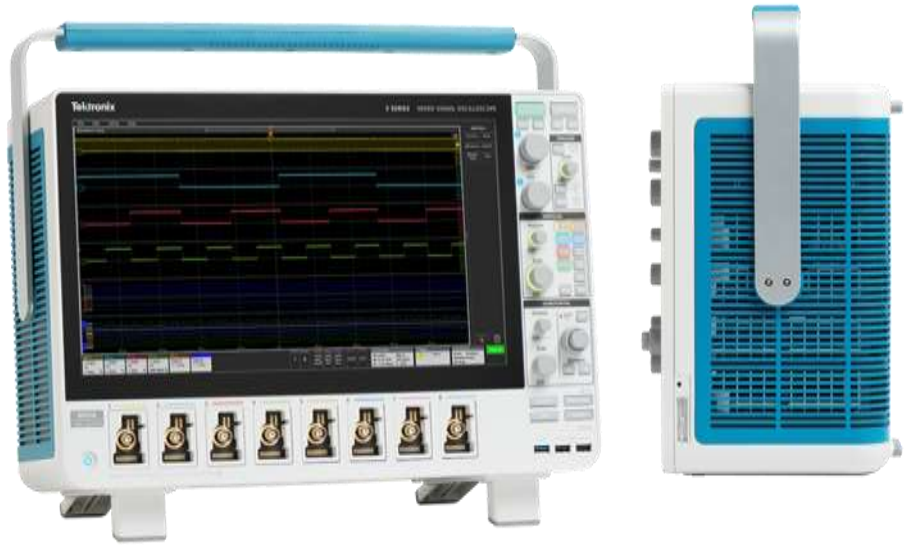
Transmitter Output Droop							
Measurement Details	Test Result	Low Limit	Measured Value	High Limit	Units	Margin	Run#
Positive Output Droop_50ohm	Pass	NA	3.457	30	%	LL: N.A, HL: 26.543	1
Negative Output Droop_50ohm	Pass	NA	3.52	30	%	LL: N.A, HL: 26.48	1
Positive Output Droop_50ohm	Pass	NA	3.446	30	%	LL: N.A, HL: 26.554	2
Negative Output Droop_50ohm	Pass	NA	3.809	30	%	LL: N.A, HL: 26.191	2
Positive Output Droop_50ohm	Pass	NA	3.245	30	%	LL: N.A, HL: 26.755	3
Negative Output Droop_50ohm	Pass	NA	3.219	30	%	LL: N.A, HL: 26.781	3
Positive Output Droop_50ohm	Pass	NA	3.47	30	%	LL: N.A, HL: 26.53	4
Negative Output Droop_50ohm	Pass	NA	3.792	30	%	LL: N.A, HL: 26.208	4
Positive Output Droop_50ohm	Pass	NA	3.296	30	%	LL: N.A, HL: 26.704	5
Negative Output Droop_50ohm	Pass	NA	3.787	30	%	LL: N.A, HL: 26.213	5
COMMENTS	Signal Validation : Pass. Signal Validation passed For run 5: 50ohm mode : Positive droop :Max value = 3.64%, Min value = 2.92%, Count = 19 50ohm mode : Negative droop :Max value = 4.15%, Min value = 3.55%, Count = 18						

Back to Summary Table

Hardware Platform

THE MOST FLEXIBLE AND CAPABLE SCOPE FOR AUTOMOTIVE APPLICATIONS

5 Series MSO	MSO54	MSO56	MSO58	MSO64
Bandwidth	350 MHz, 500 MHz, 1 GHz, 2 GHz			1GHz-8GHz
Maximum Analog Channels	4	6	8	4
Maximum Digital Channels (optional in 8 channel increments)	32	48	64	32
Sample Rate (all A&D ch.)	6.25 GS/s			25GS/s
Standard Record Length (all A&D ch.)	62.5 M			
Max. Opt. Record Length (all A&D ch.)	125 M			
Waveform Capture Rate	500,000 wfms/s			
ADC Resolution	12 bits			
Vertical Resolution	8 bits at 6.25 GS/s 12 bits at 3.125 GS/s Up to 16 bits w/ High Res			
Arbitrary/Function Generator	Up to 50 MHz (opt.)			
Integrated DVM & Trigger Freq. Counter	Free with product registration			
Price Range	$12,600 − $40,600			



Oscilloscope
Logic Analyzer
Arbitrary/Function Generator
Protocol Analyzer
DVM
Trigger Frequency Counter

10BASE-T1S Compliance Solution

- Oscilloscope: MSO 5/6 Series
  - 350 MHz minimum bandwidth
- Software:
  - 5/6-CMAUTOEN10: 10BASE-T1S compliance
  - Optional Advanced jitter software
- Probes: TDP1500 (2 required)
- Signal source: AFG31052
- Fixtures: TF-XGbT Ethernet test board
- Accessories: As per Datasheet

Summary

- Reliability Test: Design Engineers can perform System level Signal Integrity test with different scenarios to uncover final integration issues.
- Most accurate Protocol decode solution for Automotive Ethernet
- Compliance Test: coverage of all Ethernet variants as per Open Alliance TC8 and Component test specification
- Component to System level test for In-Vehicle Network standards

Automotive Ethernet Solution

- Oscilloscope: MSO 5 Series,DPO70KC
  - 350MHz minimum bandwidth (10BASE-T1S)
  - 1 GHz minimum bandwidth (100BASET1)
  - 2GHz Minimum bandwidth (1000BASET1)
- Compliance Software:
  - 5/6-CMAUTOEN10 10BASE-T1S compliance
  - 5/6-CMAUTOEN: 1000BASE-T1/100BASE-T1 compliance
- Signal Integrity Test with Signal Separation:
  - 5/6-AUTOEN-SS: 100/1000BASE-T1 Automotive Ethernet Signal Separation
  - 5/6-PAM3: PAM3 Signal Analysis (Prerequisite:5/6-DJA)
- Protocol Decode:
  - 5/6-SRAUTOEN1: 100BASE-T1 Protocol decode
- Probes: TDP1500- 10BASE-T1S/100BASET1
  TDP3500 - 1000BASET1
- Signal source: AFG310000series
- Network Analyzer: TTR503/506
- Fixtures: TF-XGbT Ethernet test board
  TF-BRR-CFD Clock divider

Automotive IVN solution

Standard	Tek solution	Platform
CAN/CAN-FD	Protocol decode	MSO4/5/6, MDO3, DPO70K*
LIN	Protocol decode	MSO4/5/6, MDO3, DPO70K*
FlexRay	Protocol decode	MSO4/5/6, MDO3, DPO70K*
SENT	Protocol decode	MSO4/5/6
PSI5	Protocol decode	MSO4/5/6
10BASE-T1S	Compliance	MSO5/6
100BASE-T1	Compliance, Protocol decode	MSO5/6, DPO70K*
1000BASE-T1	Compliance	MSO5/6, DPO70K*
100/1000BASE-T1	Signal Integrity Analysis	MSO5/6
LVDS	Transmitter Test	MSO5/6, DPO70K*

Tektronix

Thank you!

Tektronix

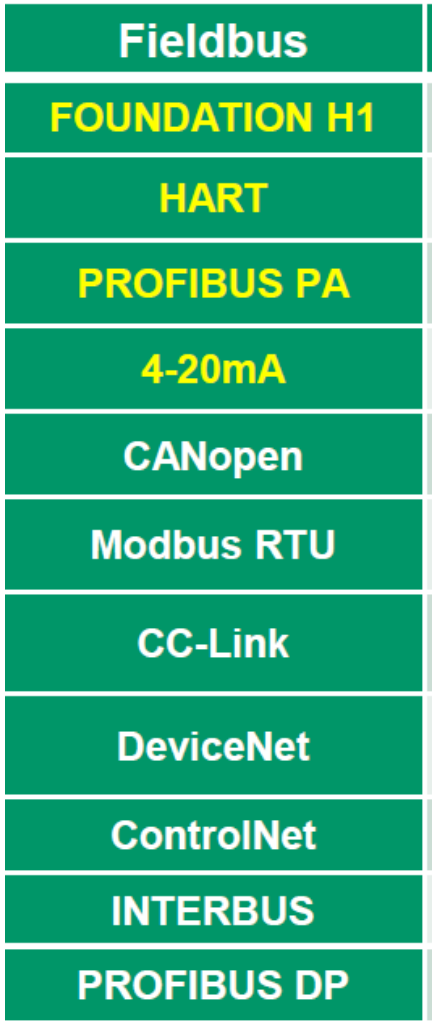
10BASE-T1L

Validation and Compliance Testing

1 MARCH 2021

Industry standards for 10Mbps

- Existing 10Mbps standards
  - Industrial: HART Modem, RS232, RS485, Ethernet, Canopen
  - Proprietary standards, require separate line for Power, Simplex communication
  - Fieldbuses/other non-ethernet standards still require completing communication to edge which need complex bridge/switch
  - Challenges with combined reach & rate, special environments, cost of operation.
- **10BASE-T1L**
  - Target Segments**:-** Industrial networks, Intelligent building networks, HVAC, security/access, lighting, IoT, control and actuator based devices and systems



pressures.

- Zone 0: Area in which an explosive gas-air mixture is continuously present or present for long periods.
- Zone 1: Combustible or conductive dusts are present. Area in which an explosive gas-air mixture is likely to occur for short periods in normal operation.
- Zone 2: Area in which an explosive gas-air mixture is not likely to occur, and if it occurs it will only exist for a very short time due to an abnormal condition.

Different protection methods are applied in the zones. The intrinsic safety method (Ex i) strictly limits energy by appropriate protective circuit design in order to avoid any explosion in case of faults. Ex i is the preferred method in Zone 0. The increased safety method (Ex e) is less restrictive for powering devices and appropriate for Zone 1.

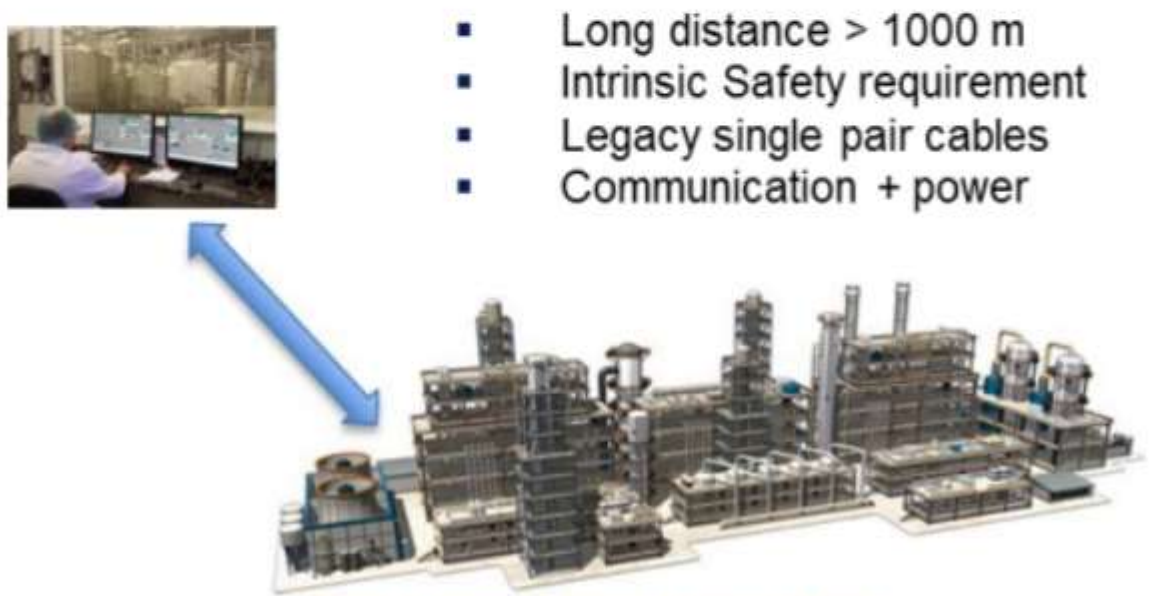


Figure 4: Example Process Automation plant

With a migration to Ethernet, a switched architecture (Figure 5) will be adopted. This is a transition from the homerun wiring of 4-20mA and from the multi-drop topology of the fieldbuses. Upgrades in the marshalling cabinets (Zone 2, near the control room), the field junction boxes (Zone 1), and the field devices (Zone 0) give access to cable ends for a simplified transition.

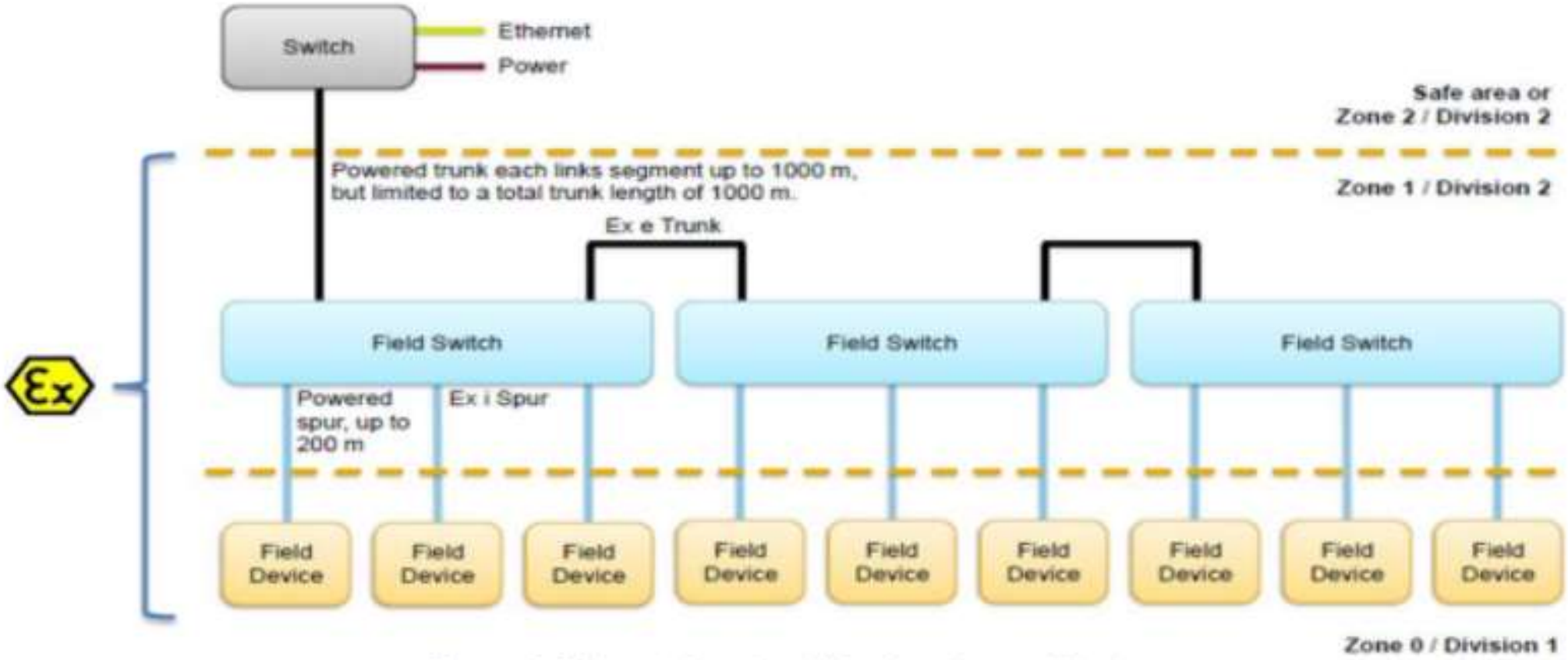


Figure 5: Ethernet-based switched system architecture

In order to reduce installation costs and cabling effort, the connection to the field is realized by a *Trunk* and *Spurs* as depicted in both Figure 5 and Figure 6. The Trunk and Spur provide sufficient bandwidth for the communication into the field and provide the field devices with power. Ideally, the Trunk and Spur utilize single twisted pair shielded cable as described by IEC 61158-2 type A cable.

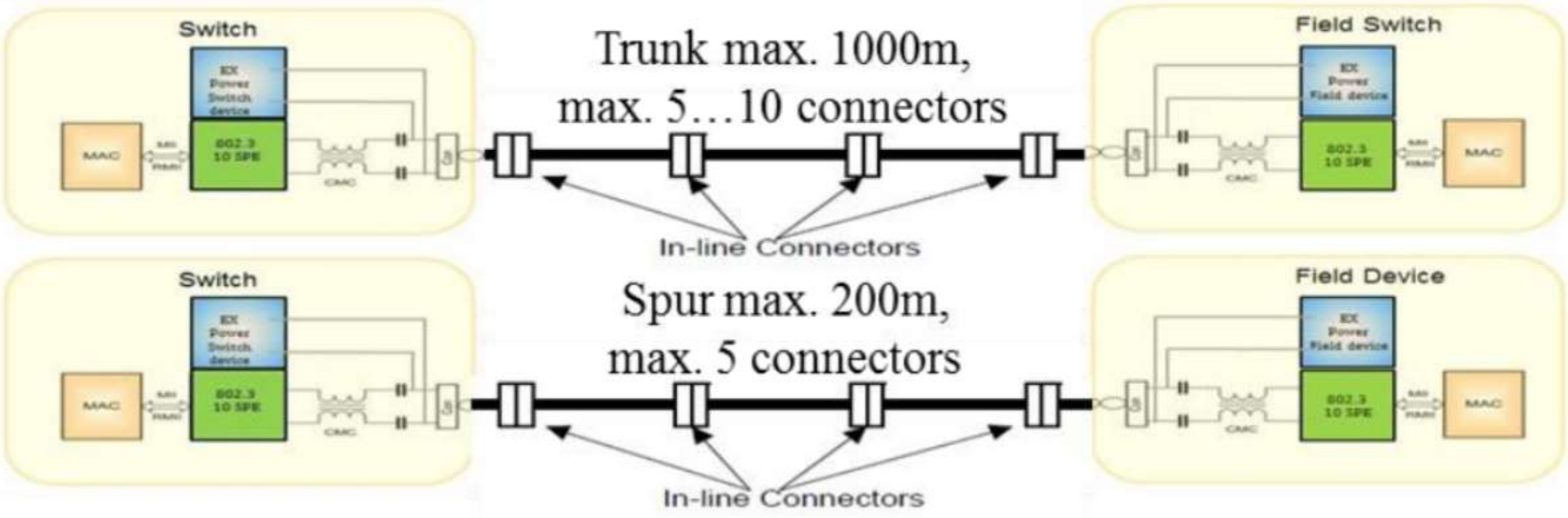


Figure 6: Trunk and Spur

10SPE emerges to fill Ethernet edge gaps

- In July 2016, the IEEE 802.3 authorized the “10 Mb/s Single Twisted Pair Ethernet Study Group” (informally known as “10SPE”), kicking off the development of a set of Ethernet enhancements aimed at closing the gaps for Ethernet edge devices.
- Participating industries included: Industrial Automation, Automotive, Building Automation and Lighting.
- Both are satisfied by a 10 Mb/s rate. The target application are not currently very demanding. Process Automation migrates from 31.25 kb/s. Future upgrade of rate is anticipated by the optional AutoNegotiation objective.

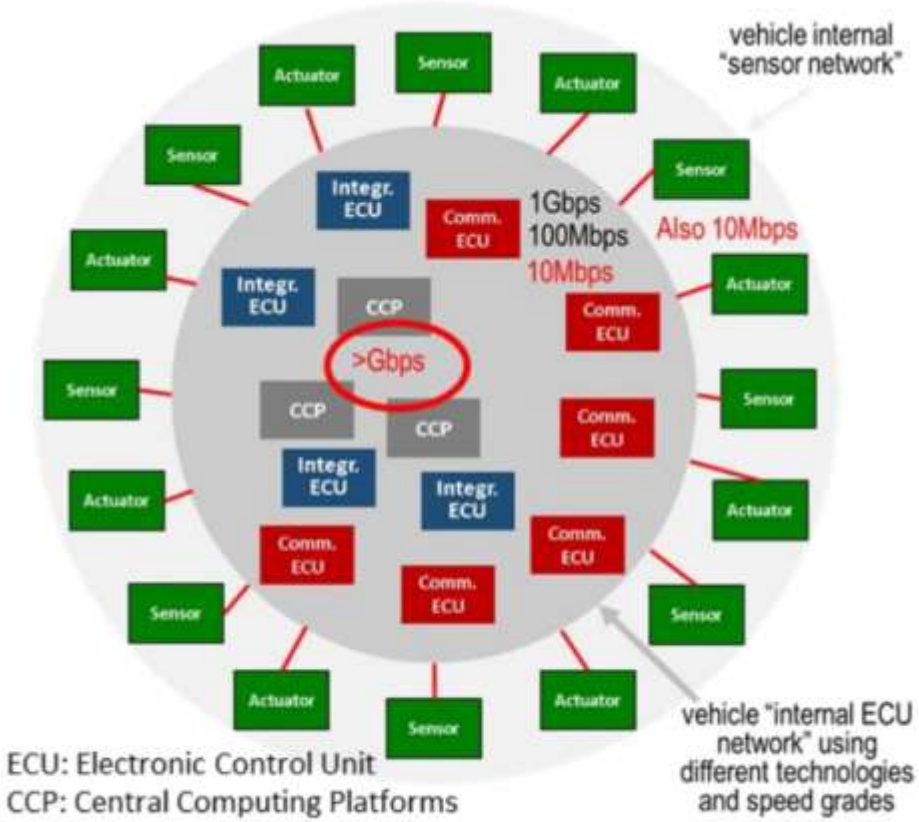


Figure 7: Automotive Ethernet architecture concept

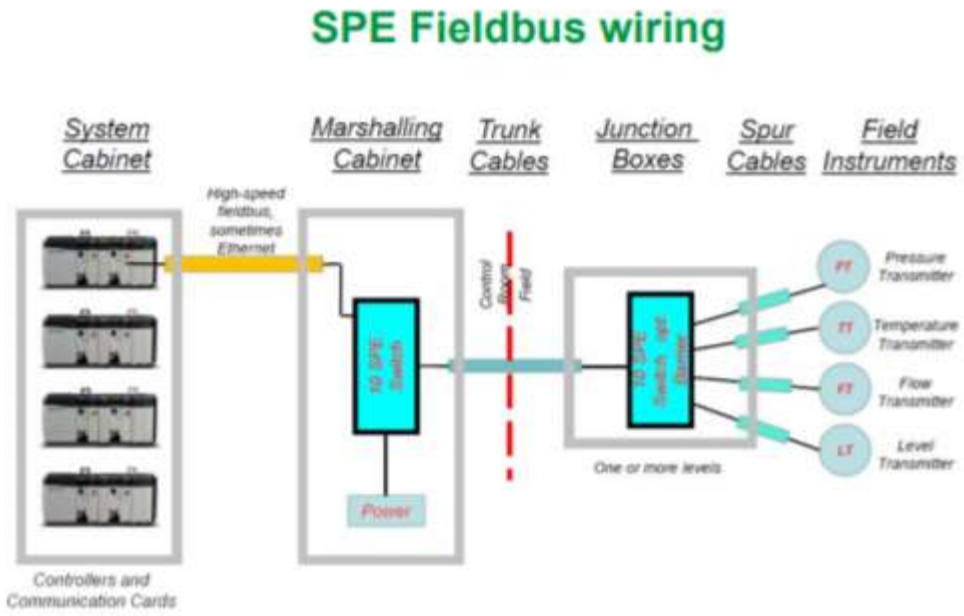
SPE Standards

- Draft standard: IEEE P802.3ch Multi-Gig Automotive Ethernet PHY Task Force
  - 2.5GBASE-T1 – 2.5 Gb/s operation over link segment supporting up to four in-line connectors using a single shielded balanced pair of conductors for up to at least 15 m
  - 5GBASE-T1 – 5 Gb/s operation over link segment supporting up to four in-line connectors using a single shielded balanced pair of conductors for up to at least 15 m
  - 10GBASE-T1 – 10 Gb/s operation link over segment supporting up to four in-line connectors using a single shielded balanced pair of conductors for up to at least 15 m

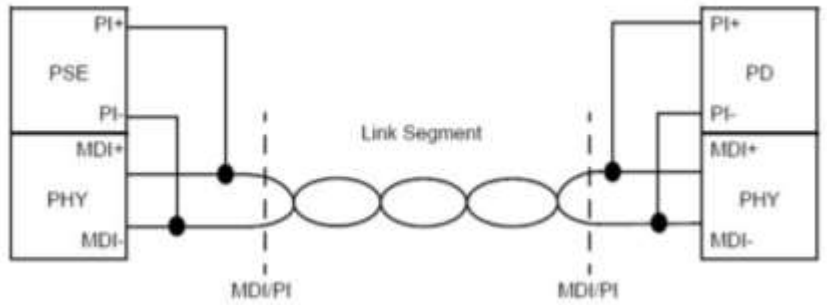
- Draft standard: IEEE P802.3cg 10 Mb/s Single Pair Ethernet Task
  - 10BASE-T1S – 10 Mb/s operation over a short reach single balanced twisted-pair link segment supporting up to ten in-line connectors for up to at least 15 m.
  - 10BASE-T1L – 10 Mb/s operation over a long reach single balanced twisted-pair link segment supporting up to ten in-line connectors for up to at least 1000 m.

Why 10BASE-T1L?

- Standardization: IEEE 802.3cg Open standard
- Based on well-proven Ethernet technology but customized for additional Industrial needs
- Co-exists with existing Ethernet networks
- PAM3 Modulation, Long reach (upto 1KM)
- Single pair, Full-Duplex communication
- Power Over Data Line (PoDL): optional Type E PoDL remote power provisioning.
- Four classes of Type E power sourcing equipment (PSE), support up to a minimum of 13.6W over up to 1 km of single balanced pair point-to-point cabling



Ethernet and 10BASE-T1L

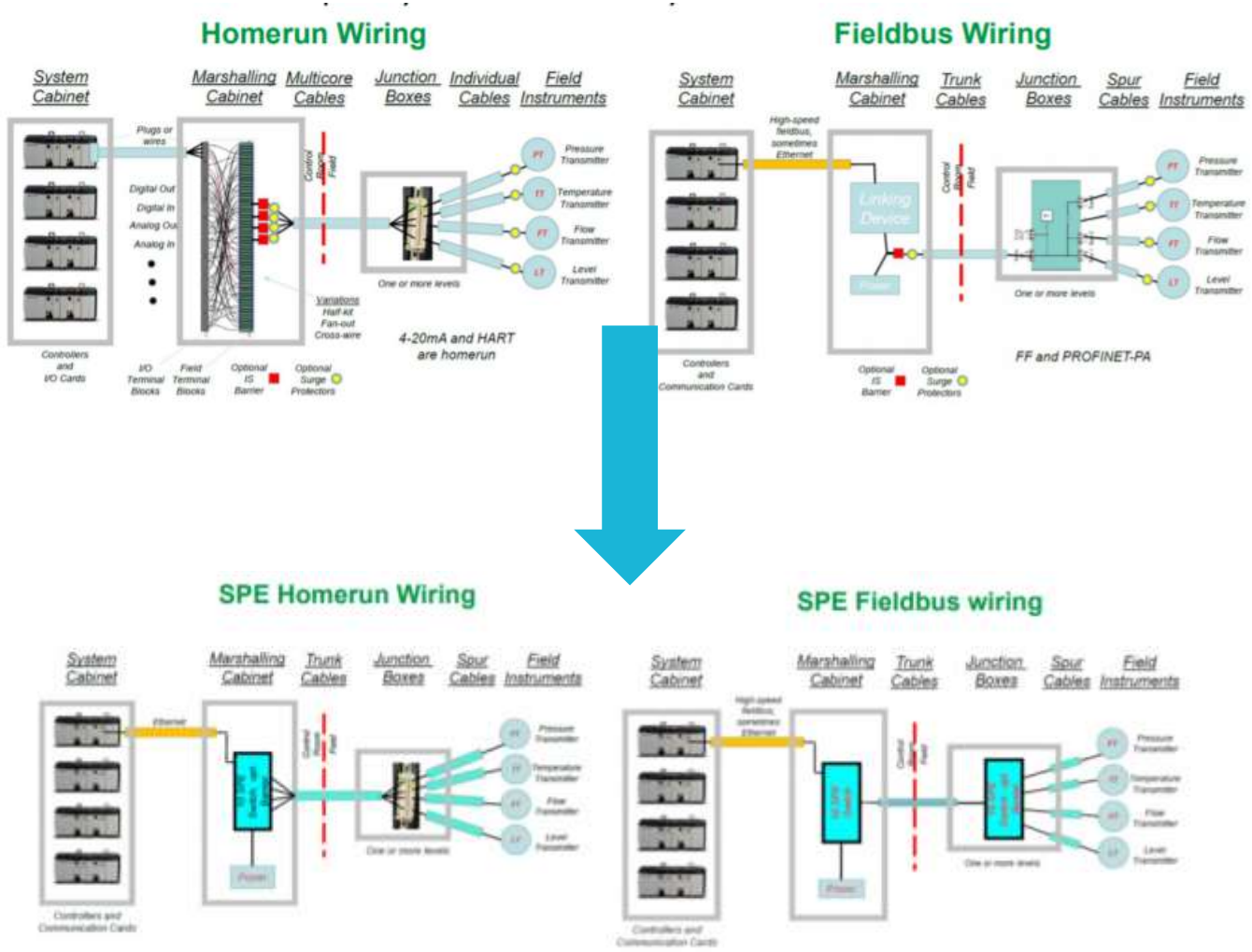


PoDL

10BASE-T1L Architecture

- Multi-drop: Multi-drop link segments (that form tree structures) will be replaced by multi-port switches that break the multi-drop into multiple shorter point-point link segments
- Marshalling cross-connections: 10 SPE will extend the fieldbus trend of replacing marshalling wiring complexity with switches and end node addressing

https://automationforum.co/what-is-marshalling-cabinet-or-marshalling-panel/



Ethernet v/s 10BASE-T1L Standard

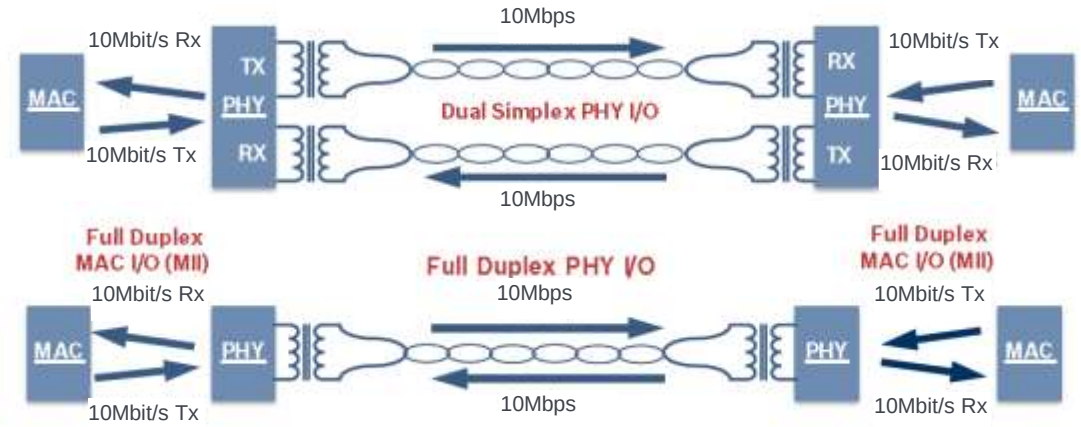
BASED ON ESTABLISHED ETHERNET STANDARDS, ADAPTED FOR AUTOMOTIVE

Standard	10BASE-T	10BASE-T1
Speed	10Mbps	10Mbps
Modulation	NRZ	PAM3
Symbol rate	10MBd	7.5Mbd
Power over Ethernet	optional, PoE	Optional PoDL
Architecture	Point to Point, two pair, Simplex	Point to point, single pair, Full Duplex
Operating voltage	+2.5V or -2.5V	1V or 2.4V
Range	100m	1000m

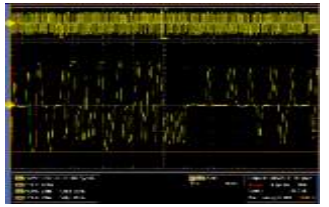
10BASE-T

10BASE-T1L

UTPC



NRZ



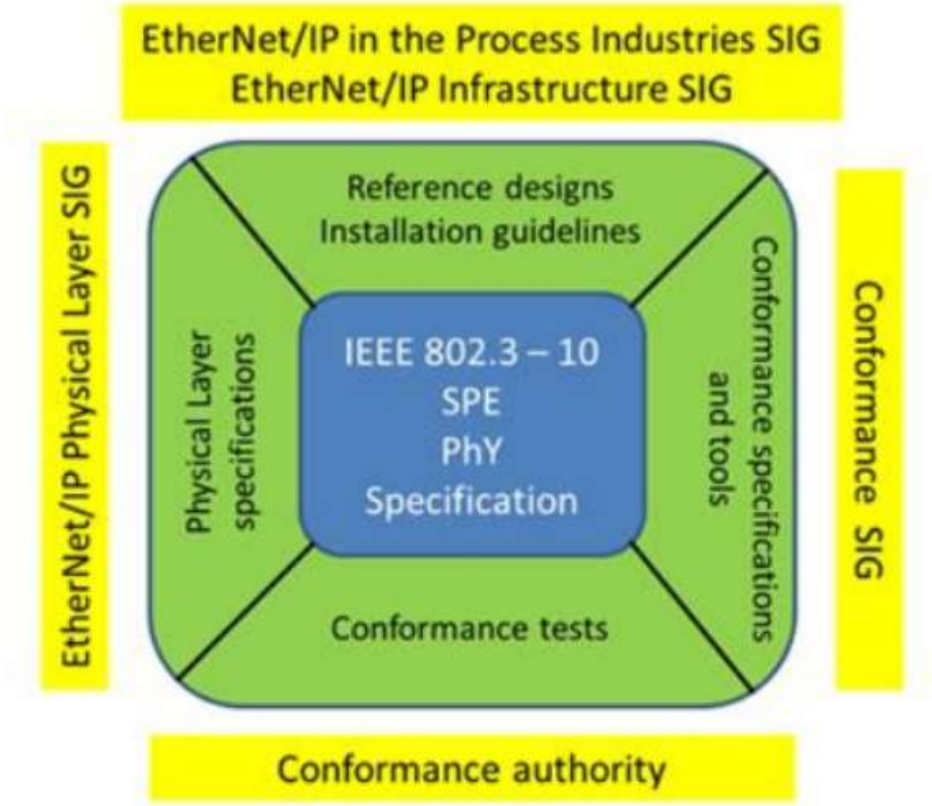
PAM3

NAMUR and ODVA

TARGET CUSTOMERS:• SILICON COMPANIES: ANALOG DEVICES. LINERTECH, RENESAS, MARVELL, MICROCHIP

INDUSTRIAL SYSTEM COMPANIES: SIEMENS, CISCO, ROCKWELL, JOHNSON CONTROL, HIRSCHMAMN, TURCK, PHOENIX, SCHNEIDER, EMERSON, ABB, PEPPERL, HUAWEI ETC

- NAMUR is an international user association of automation technology in process industries. We have been representing the interests of our members for more than 65 years. NAMUR currently numbers 162 member companies, 8 for China
- Founded in 1995, ODVA is a global association whose members comprise the world's leading automation companies. ODVA's mission is to advance open, interoperable information and communication technologies in industrial automation



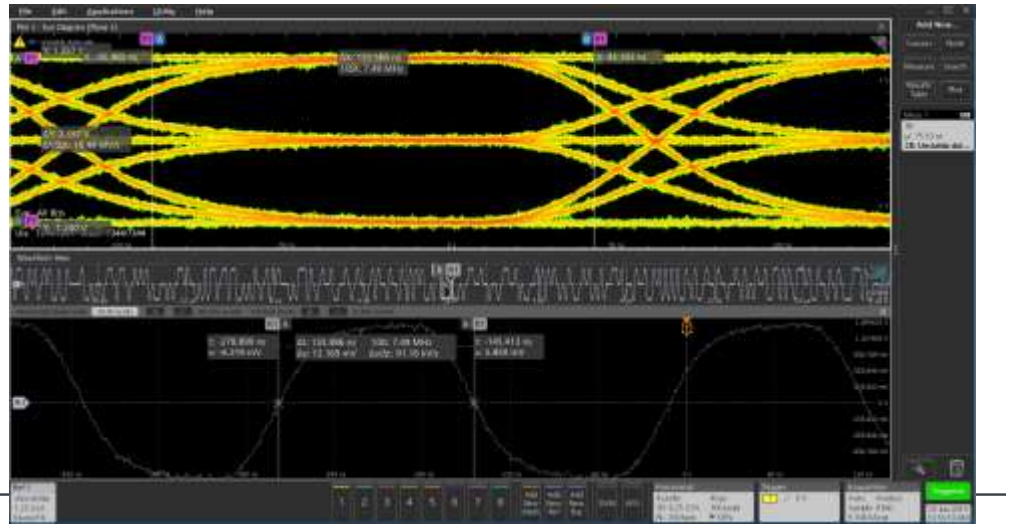
10BASE-T1L Compliance

Ensuring performance and interoperability

10BASE-T1L PMA Test Specification

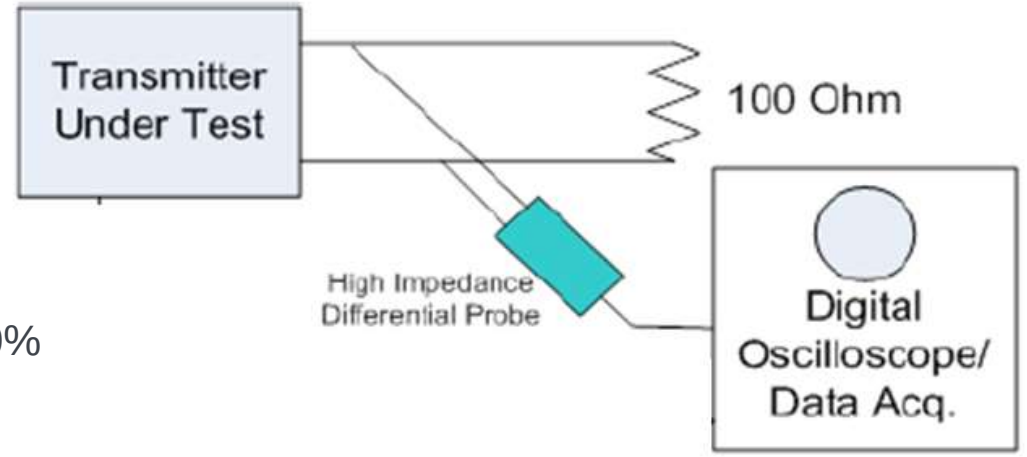
- PHY Media Attachment Compliance Test
- PHY test mode configuration should be provided by PHY vendor
- Transceiver PHY electrical test requirements include:
  - Maximum Output Droop
  - Timing Jitter
  - Power Spectral Density
  - Clock Frequency
  - MDI Return Loss
  - Peak Differential Output
- Operating mode: 1V and 2.4V
- PAM3 signaling

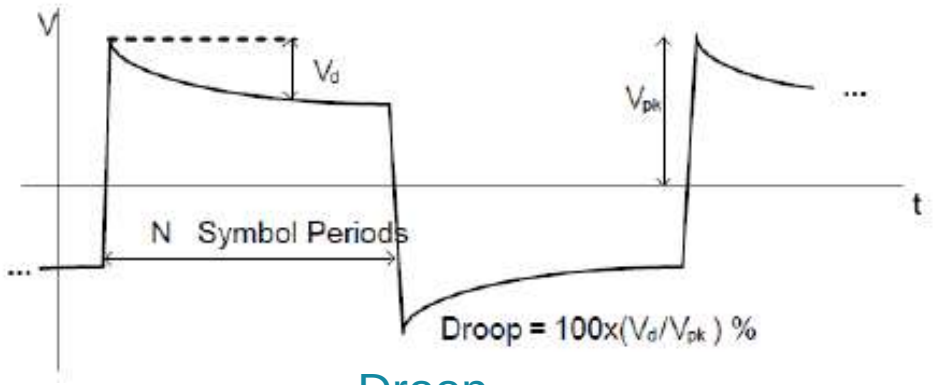
Test Name	Test Mode
Transmitter Output Droop	2
Transmitter Timing Jitter	1
Transmitter Power Spectral Density (PSD)	3
Transmitter Clock Frequency	1
Peak Differential Output	1
MDI Return Loss	slave



Maximum Droop Test

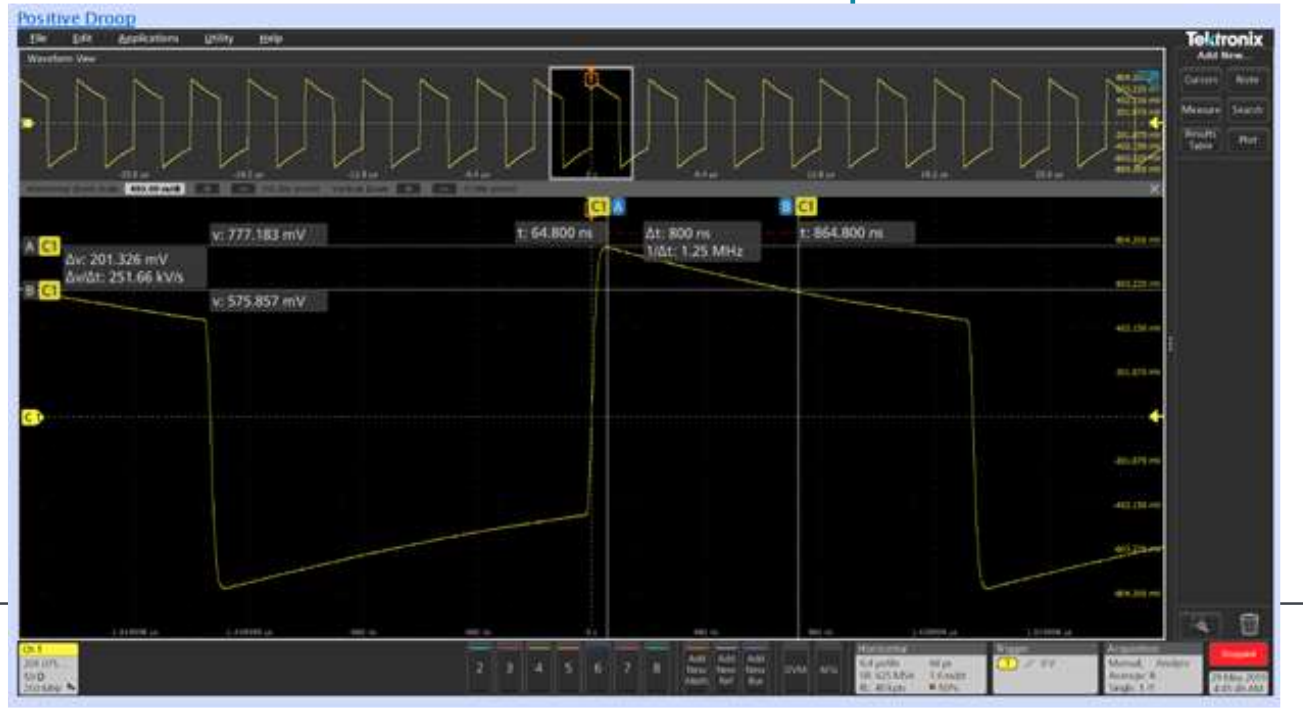
- Droop Measurement
  - Configure Test Mode 2
  - Transmit fifteen {+1} symbols followed by fifteen {–1} symbols continually
  - Value of 10 bit time pulse after initial peak, shall be less than 20.0%
  - Calculate Vpk and Vdelay as shown below
  - Vd= Vpk-Vdelay
  - Droop= vd/vpk%





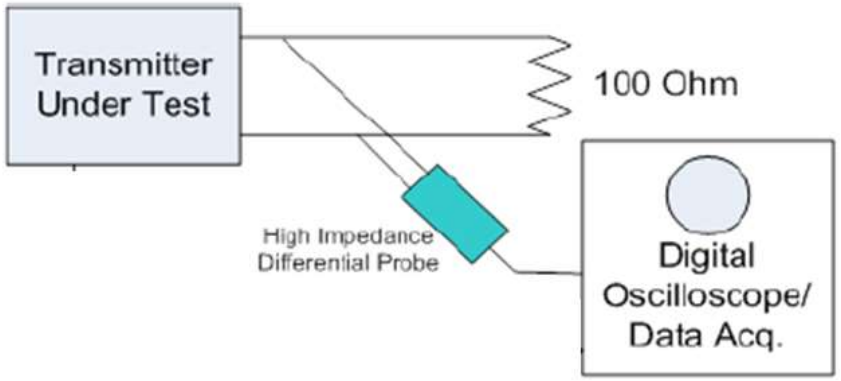
Droop

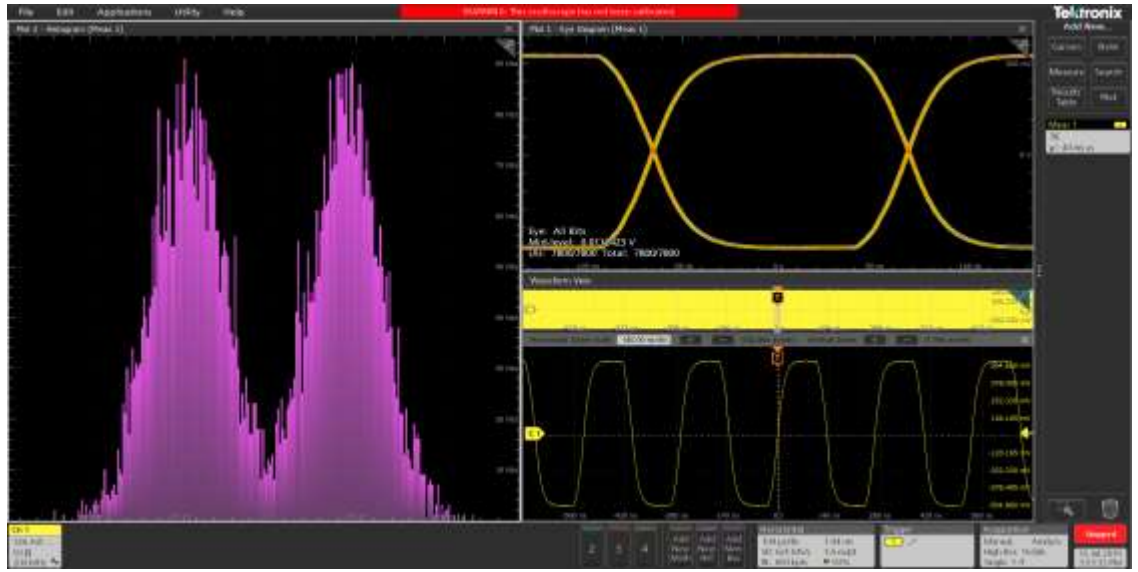
Droop



Clock Frequency and Jitter Tests

- Clock Frequency Measurement
  - Configure Test Mode 1
  - PHY device must have a symbol transmission rate of 7.5 MBd ± 50ppm
- Timing Jitter Measurement
  - Transmitter clock measurement
  - PHY output jitter shall be less than 10 ns

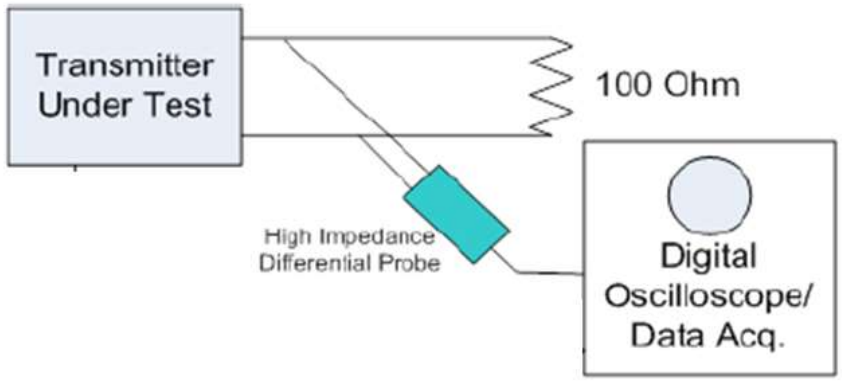




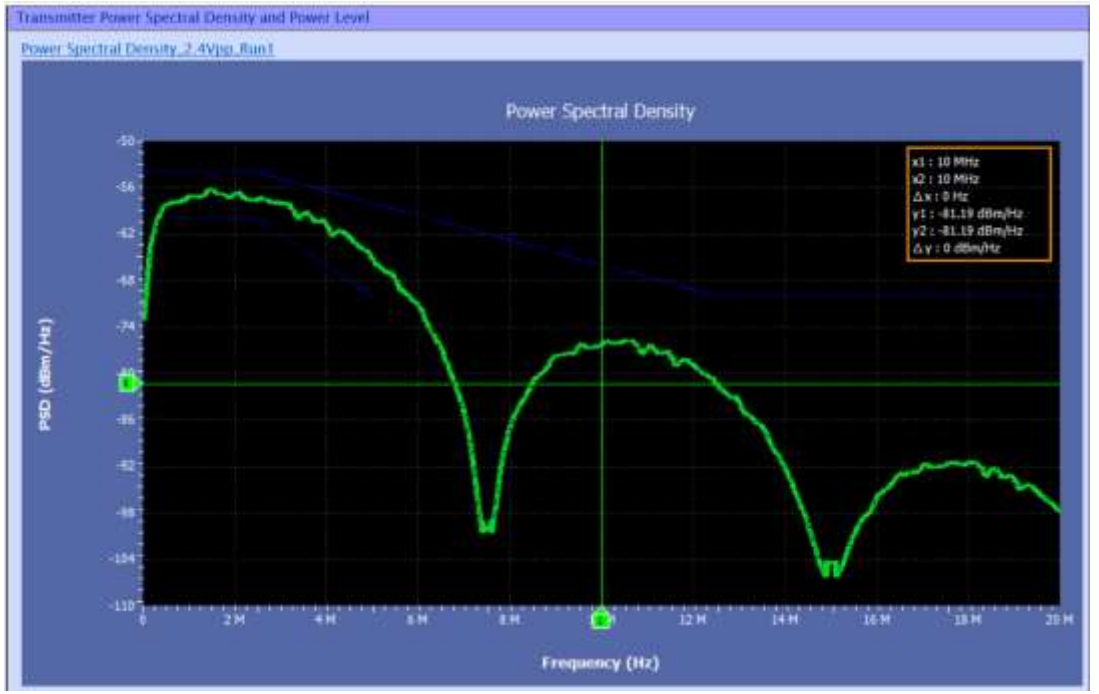
Clock Frequency & Jitter

Power Spectral Density

- Power Spectral Density
  - Configure Test Mode 3
  - Random sequence of ternary (PAM3) codes {-1, 0, +1}
  - Compliance test spec allows use of scope or spectrum analyzer
  - Power level:
    - 1.2 ± 1.0 dBm at 1Vpp operating condition
    - 8.8 ± 1.0 dBm at 2.4Vpp operating condition
  -

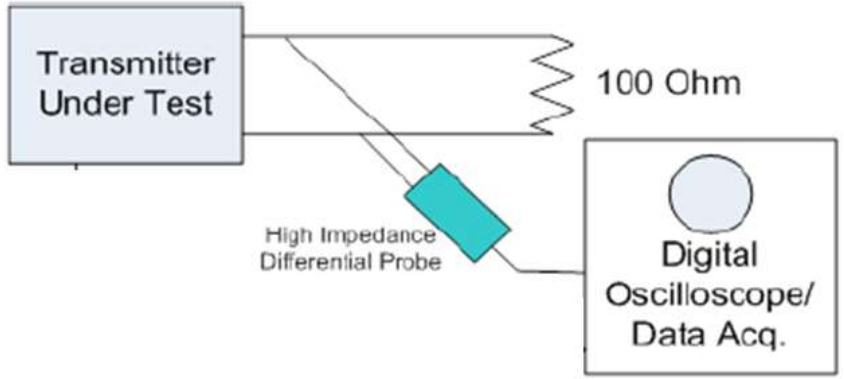


Power Spectral Density

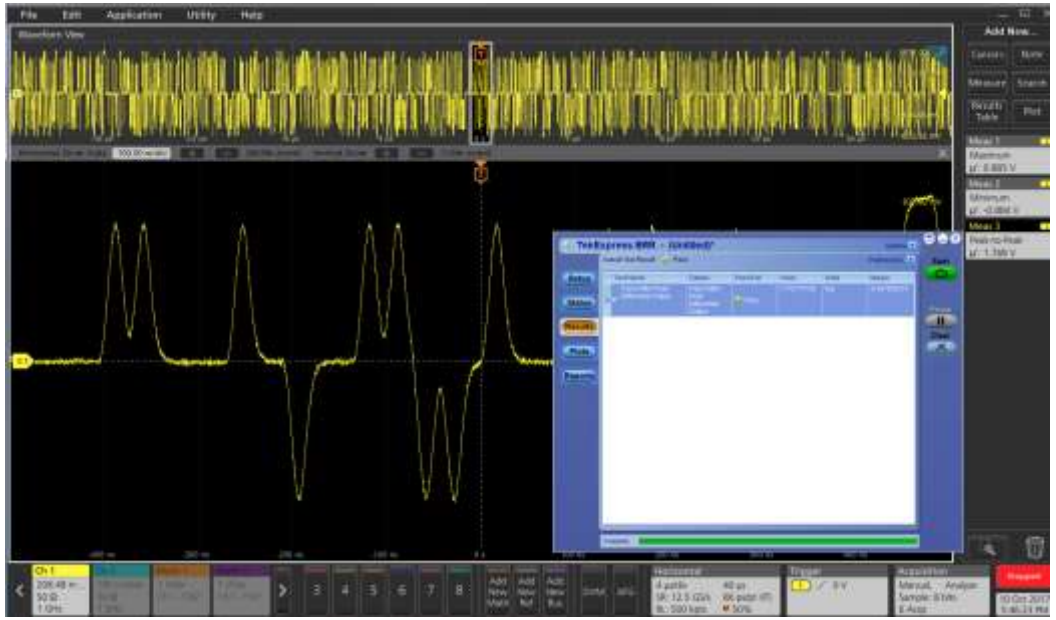


Tx Peak Differential Output Test

- Peak Differential Output Test
  - Configure device in Test mode 1
  - Peak-to-peak differential amplitude shall be 2.4 V ± 5 % peak-to-peak at 2.4Vpp operating voltage and 1 V ± 5 % peak-to-peak at 1Vpp operating voltage



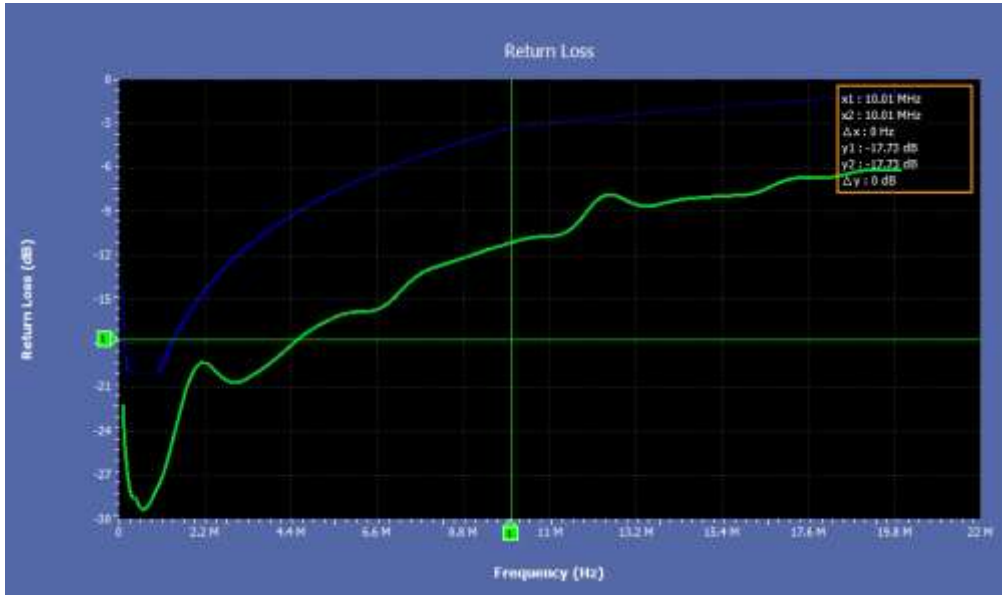
Differential Output

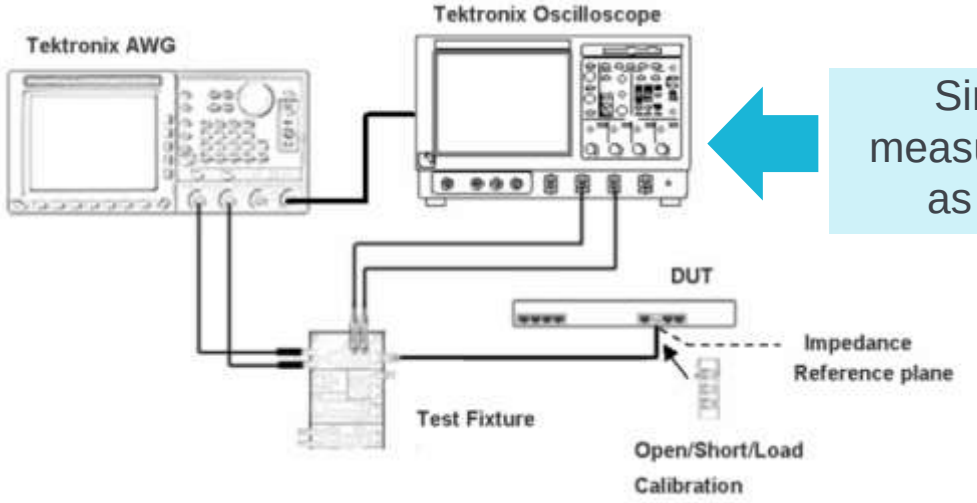


MDI (connector) Return Loss Test

- Return Loss Measurement
  - Measurement is focused on the connector and not the link (cable) return loss
  - Test spec references VNA or scope as measurement tool
  - Return loss measured at the MDI shall be at least
    20-18*log10(0.2/e) dB (0.1 to 0.2MHz)
    20dB (0.2 to 1MHz)
    20-16.7*log10(f) dB (1 to 10 MHz)
    3.3-7.6*log10(f/10) dB (10 to 20 MHz)
  - Tek has patented approach using scope and AWG (same equipment used for other tests)

Return Loss using scope

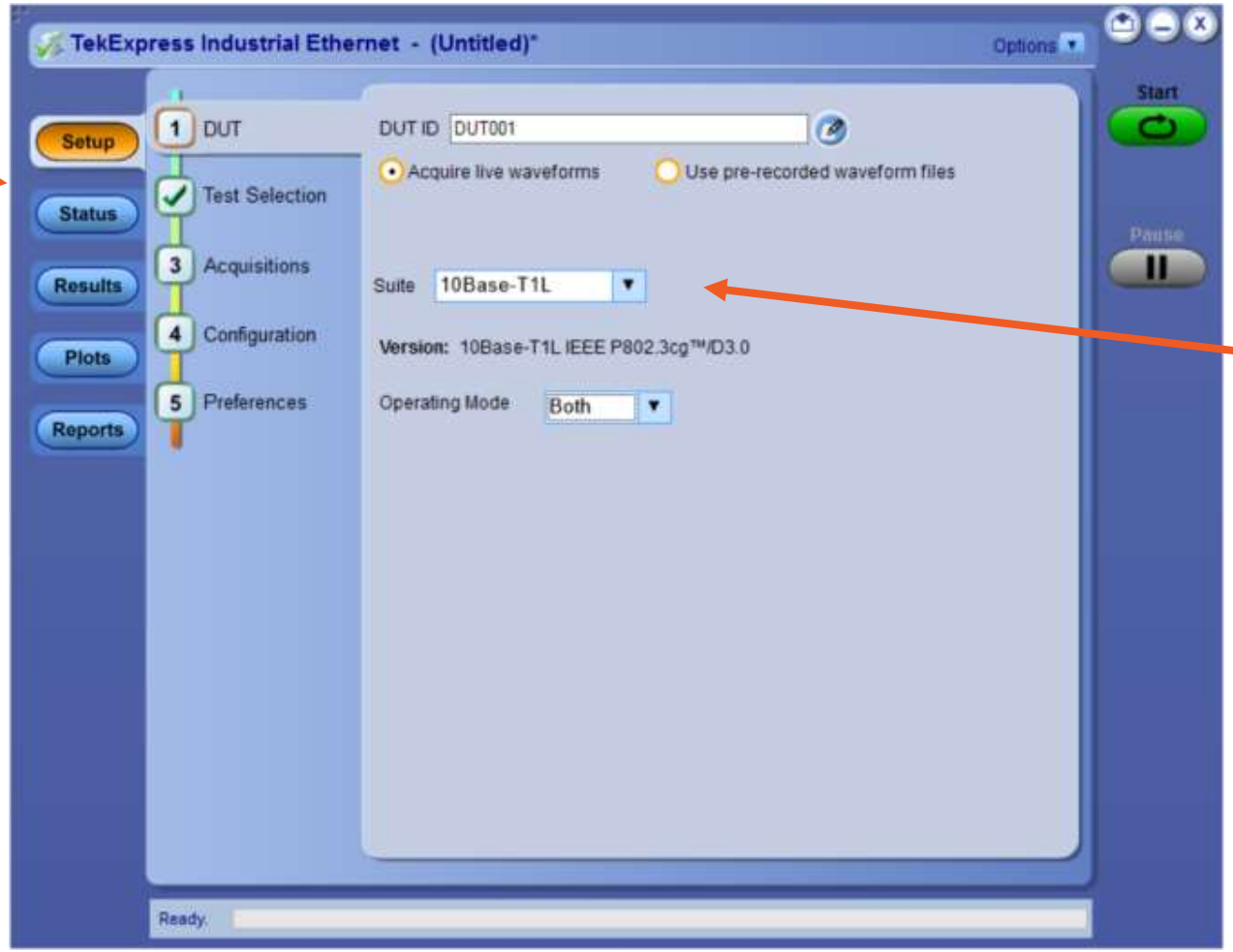




Similar measurement as VNA

Automated Compliance

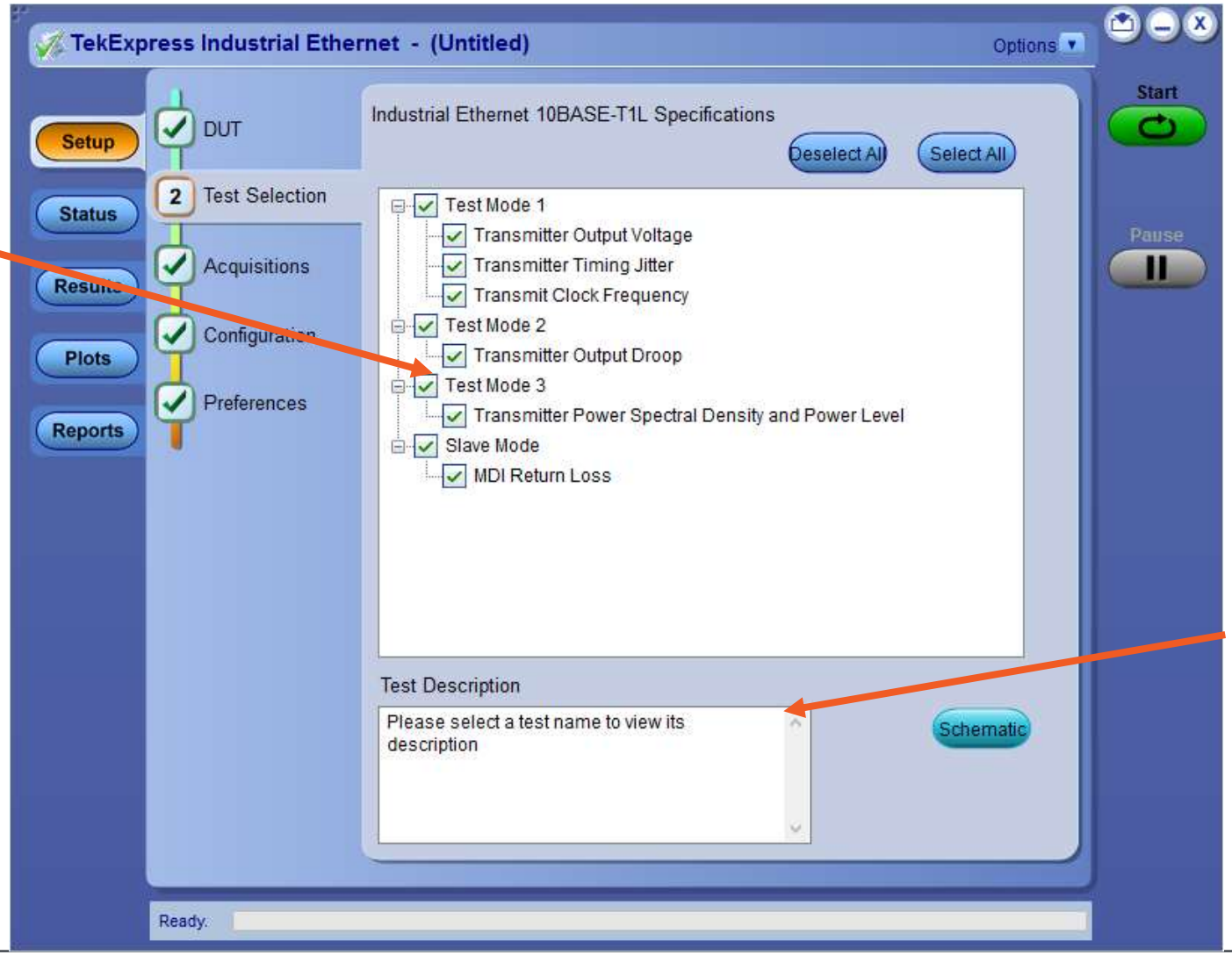
Wizard-based automation



Latest 10BASE-T1 support

Test Selection

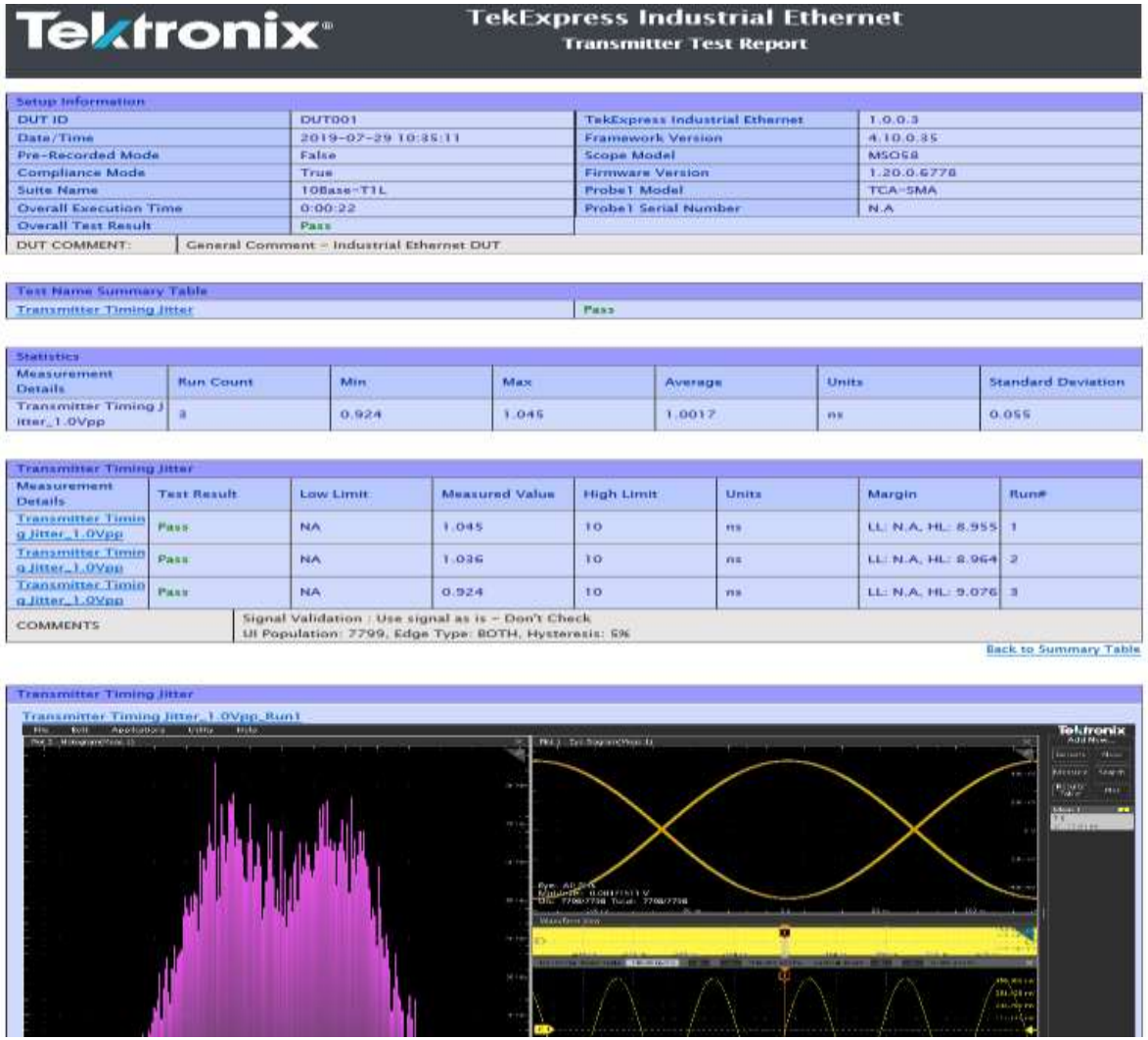
Select multiple tests



Test description with connection diagram

Automated Report Generation

Report with Pass/Fail, Margin and Plots



Tektronix®

TekExpress Industrial Ethernet
Transmitter Test Report

Setup Information

DUT ID	DUT001	TekExpress Industrial Ethernet	1.0.0.3
Date/Time	2019-07-29 10:35:11	Framework Version	4.10.0.35
Pre-Recorded Mode	False	Scope Model	MSO68
Compliance Mode	True	Firmware Version	1.20.0.6778
Suite Name	10Base-T1L	Probe1 Model	TCA-SMA
Overall Execution Time	0:00:22	Probe1 Serial Number	N.A
Overall Test Result	Pass		
DUT COMMENT:	General Comment = Industrial Ethernet DUT		

Test Name Summary Table

Transmitter Timing Jitter	Pass

Statistics

Measurement Details	Run Count	Min	Max	Average	Units	Standard Deviation
Transmitter Timing Jitter_1.0Vpp	3	0.924	1.045	1.0017	ns	0.055

Transmitter Timing Jitter

Measurement Details	Test Result	Low Limit	Measured Value	High Limit	Units	Margin	Run#
Transmitter Timing Jitter_1.0Vpp	Pass	NA	1.045	10	ns	LL: N.A, HL: 8.955	1
Transmitter Timing Jitter_1.0Vpp	Pass	NA	1.036	10	ns	LL: N.A, HL: 8.964	2
Transmitter Timing Jitter_1.0Vpp	Pass	NA	0.924	10	ns	LL: N.A, HL: 9.076	3
COMMENTS	Signal Validation : Use signal as is – Don't Check UI Population: 7799, Edge Type: BOTH, Hysteresis: 5%						

Back to Summary Table

Transmitter Timing Jitter

Transmitter Timing Jitter_1.0Vpp_Run1

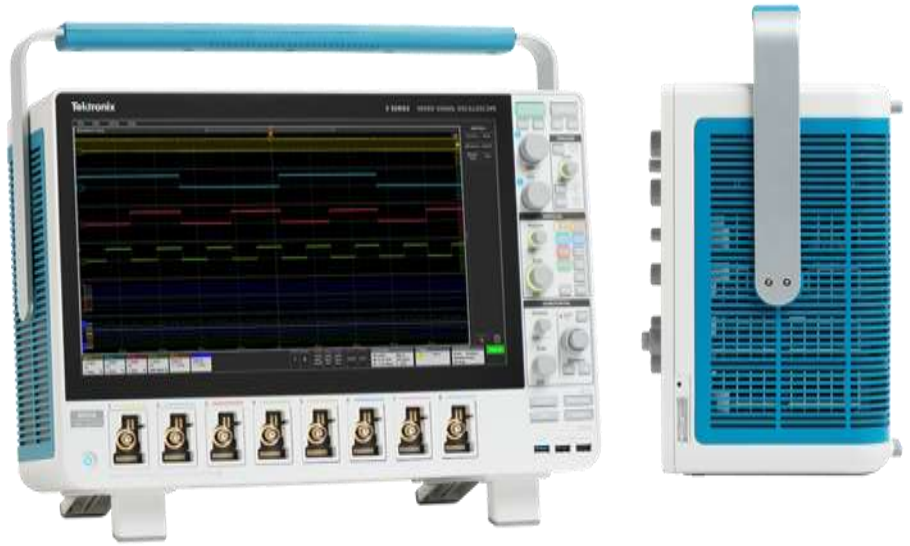
10BASE-T1L Testing

Tektronix Solutions

Hardware Platform

THE MOST FLEXIBLE AND CAPABLE SCOPE FOR AUTOMOTIVE APPLICATIONS

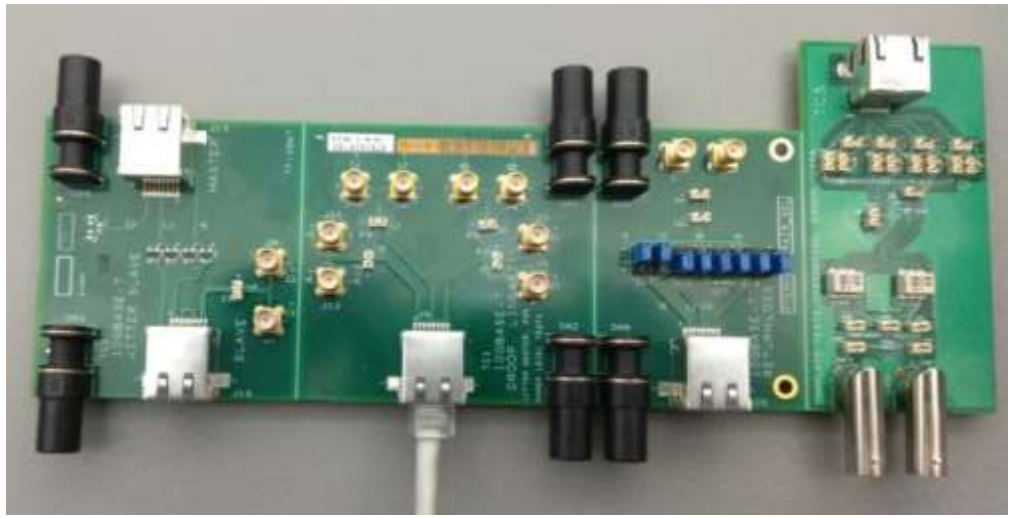
5 Series MSO	MSO54	MSO56	MSO58	MSO64
Bandwidth	350 MHz, 500 MHz, 1 GHz, 2 GHz			1GHz-8GHz
Maximum Analog Channels	4	6	8	4
Maximum Digital Channels (optional in 8 channel increments)	32	48	64	32
Sample Rate (all A&D ch.)	6.25 GS/s			25GS/s
Standard Record Length (all A&D ch.)	62.5 M			
Max. Opt. Record Length (all A&D ch.)	125 M			
Waveform Capture Rate	500,000 wfms/s			
ADC Resolution	12 bits			
Vertical Resolution	8 bits at 6.25 GS/s 12 bits at 3.125 GS/s Up to 16 bits w/ High Res			
Arbitrary/Function Generator	Up to 50 MHz (opt.)			
Integrated DVM & Trigger Freq. Counter	Free with product registration			
Price Range	$12,600 − $40,600			



Oscilloscope
Logic Analyzer
Arbitrary/Function Generator
Protocol Analyzer
DVM
Trigger Frequency Counter

Signal Access

TDP1500 Probe



TF-XGbT Fixture

10BASE-T1L Compliance Solution

- Oscilloscope: MSO 5/6 Series
  - 350 MHz minimum bandwidth
- Software:
  - 5/6-CMINDUEN10: 10BASE-T1L compliance
  - Optional Advanced jitter software
- Probes: TDP1500 (2 required)
- Signal source: AFG31052
- Fixtures: TF-XGbT Ethernet test board