Tektronix

실제 사례로 보는 Automotive Ethernet

한국텍트로닉스 AE TEAM

Agenda

ELECTRONICS IN AUTOMOTIVE

- Automotive trends
- Next generation IVN standards
  - Automotive Ethernet
  - 10BASE-T1S
- Automotive Ethernet Compliance test
- Tektronix Automotive Ethernet test solution
- Demo of 10BASE-T1S Ethernet compliance

Automotive Trends

Motivation

Challenges

Safety

Sensors, Display,
Complex Architecture

Green Energy

Battery, Range, Cost,
Power Electronics,

Connected

Wireless Standard,
Cloud, Connectivity

3.5 years

Service

Fewer Resource, Tighter Timeline

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3.5 years

Service

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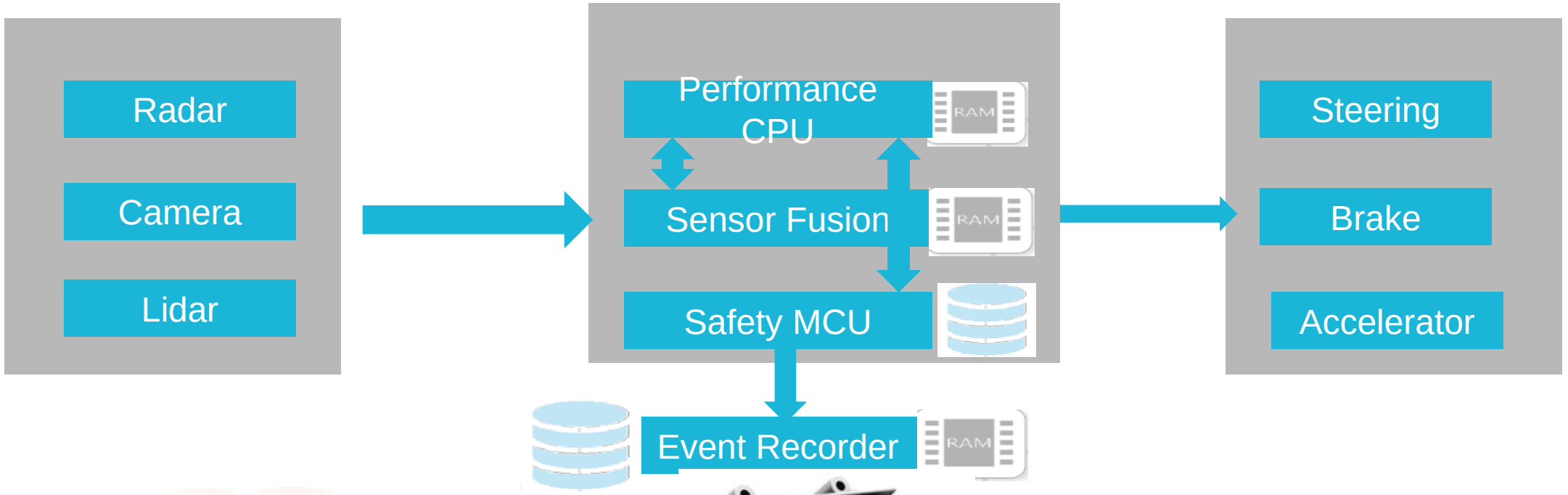
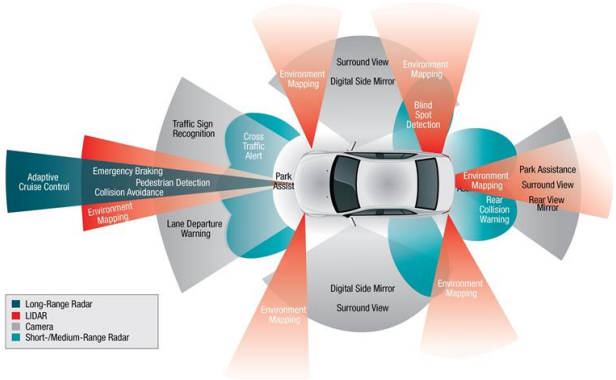
ADAS or Autonomous vehicle

LEVEL OF AUTOMATION

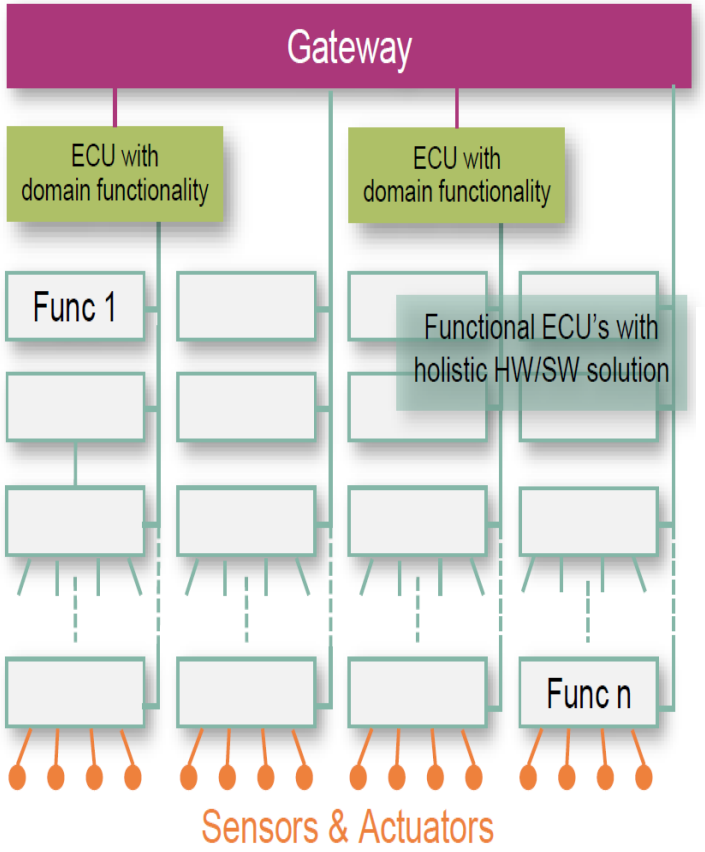
Autonomous car



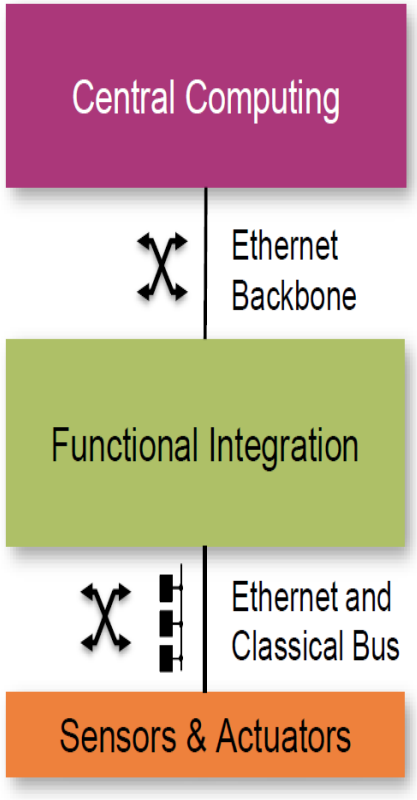


Complex Embedded Hardware

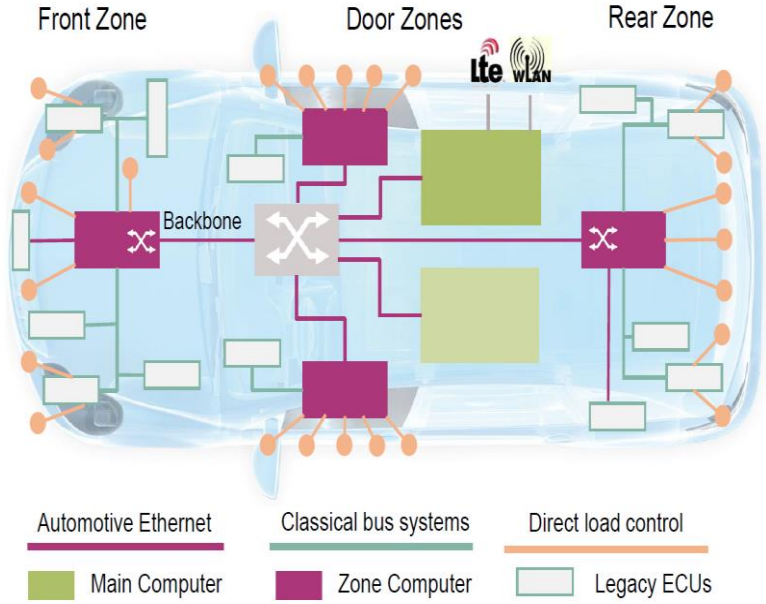
Architecture



Traditional



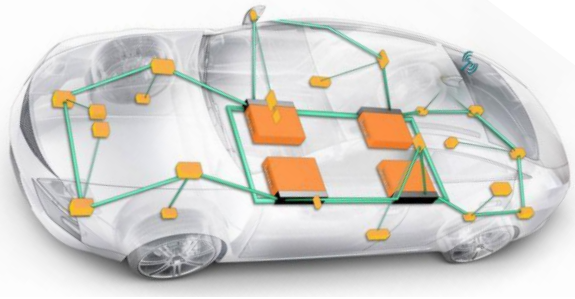
Central Processing



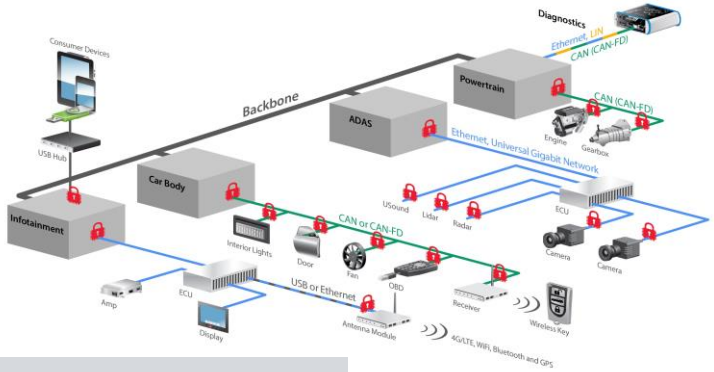
Zonal Architecture

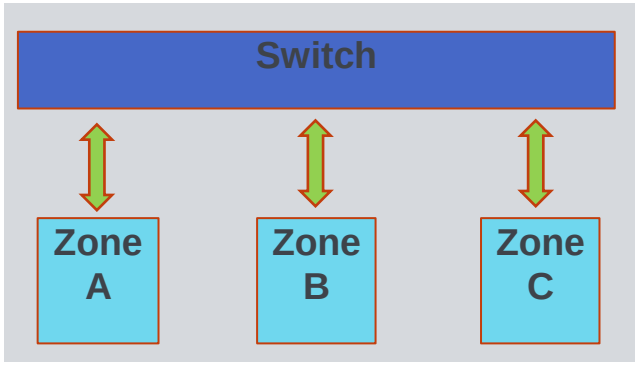
High Speed network

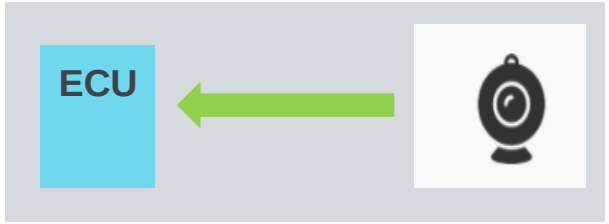
IVN Requirement



- What is IVN?
  - Electronics inside the car communicate with each other over In-Vehicle-Network.
- New Requirements:
  - Zone Architecture: Symmetrical High-speed ECU to ECU communication
  - Camera and display: Asymmetric High-speed communication
- Other requirements:
  - Reliable data transfer at Automotive harsh environment
  - EMI/EMC
  - Low weight, low cost, low power



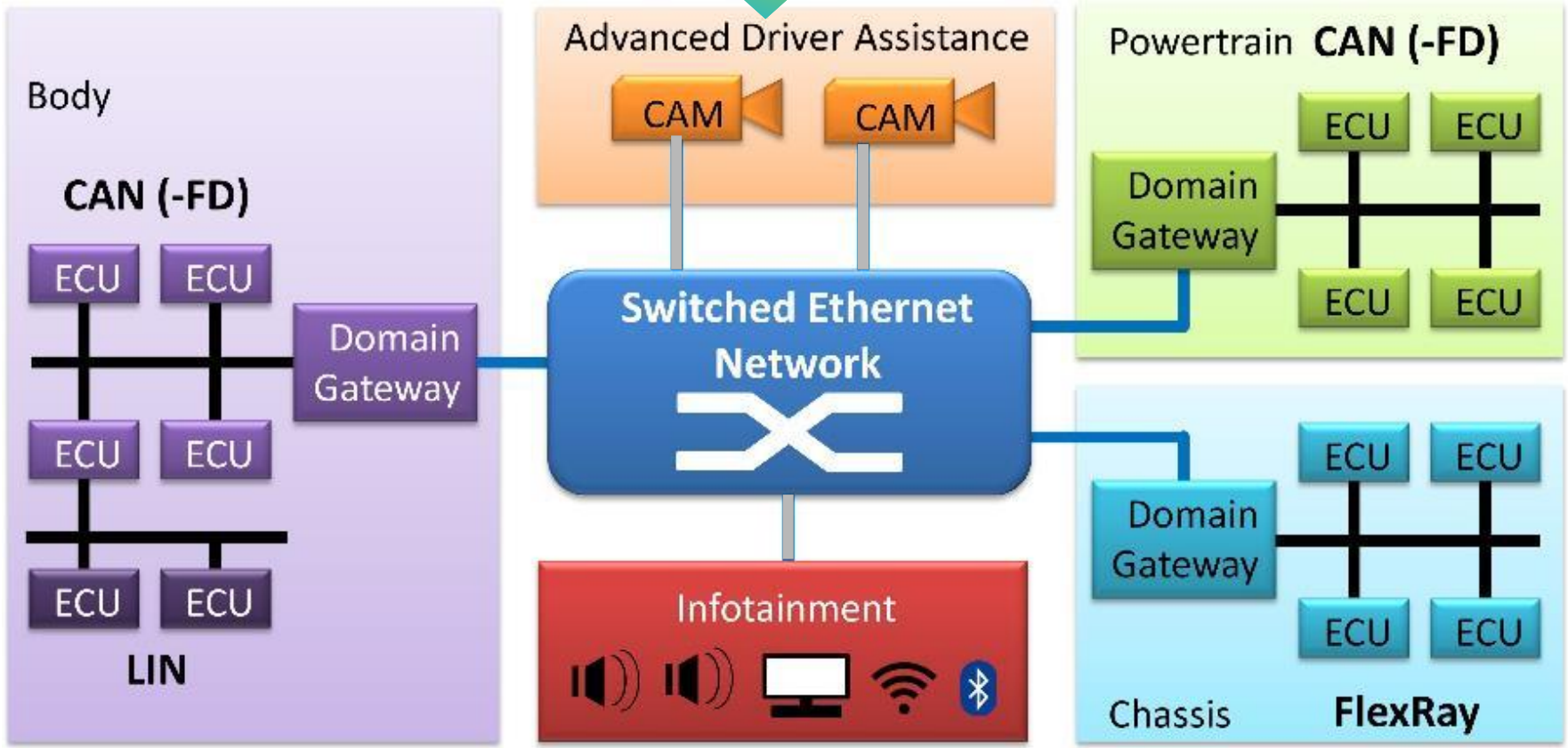




IVN standards

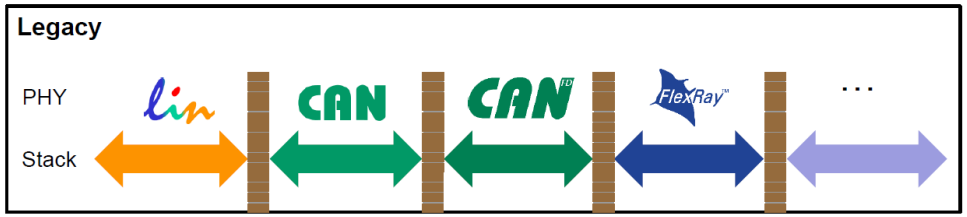
Domain Architecture

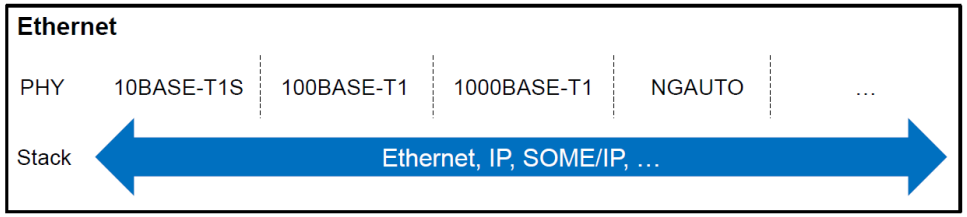
Low Speed IVN	CAN, LIN, FlexRay
Symmetric IVN	Automotive Ethernet
Asymmetric IVN	FDP-Link, GMSL, A-PHY, ASA



Automotive Ethernet Overview

- **Standards:**
  - 10BASE-T1S (802.3cg) – 10Mbps
  - 100BASE-T1 (802.3bw) – 100Mbps
  - 1000BASE-T1 (802.3bp) - 1000Mbps
  - Multigigabit Ethernet (802.3ch) – 10Gbps
  - 25G/50G Automotive Ethernet (802.3cy*)
  - Multigigabit Optical Automotive Ethernet (802.3cz*)
- **What is the difference between Ethernet and Auto Ethernet?**
  - Single pair of cable
  - Full-Duplex communication
  - PAM3/4 modulation
- **Why Automotive Ethernet?**
  - Derived from proven Ethernet standards
  - Offers Common Architecture with multiple speed option
  - Cost: Unshielded cable, Full-duplex cable reduces cost and cable weight



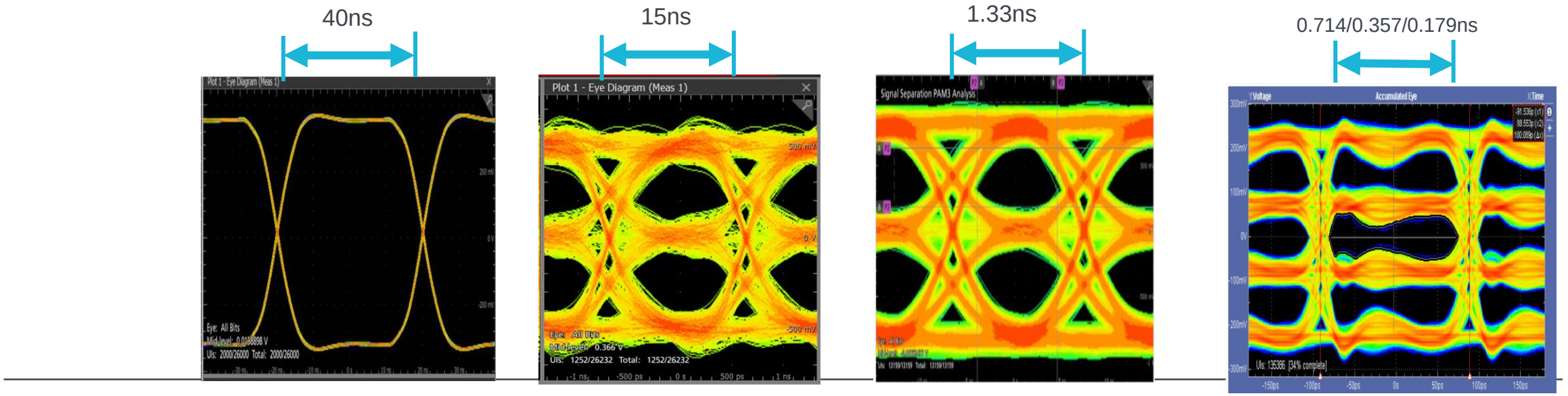


OSI	Automotive Ethernet
7 Application	Applications (HTTP, FTP, SMTP..)
6 Presentation	
5 Session	
4 Transport	TCP
3 Network	IP
2 Data Link	Network Access
1 Physical	10/100/1000/NGBASE-T1

* Under development

Automotive Ethernet- 10Mbps to 10Gbps

	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, DME	PAM3	PAM3	PAM4
Voltage	1Vpp	2.2Vpp	1.3Vpp	1.3Vpp
Communication	Half/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



Low speed Applications

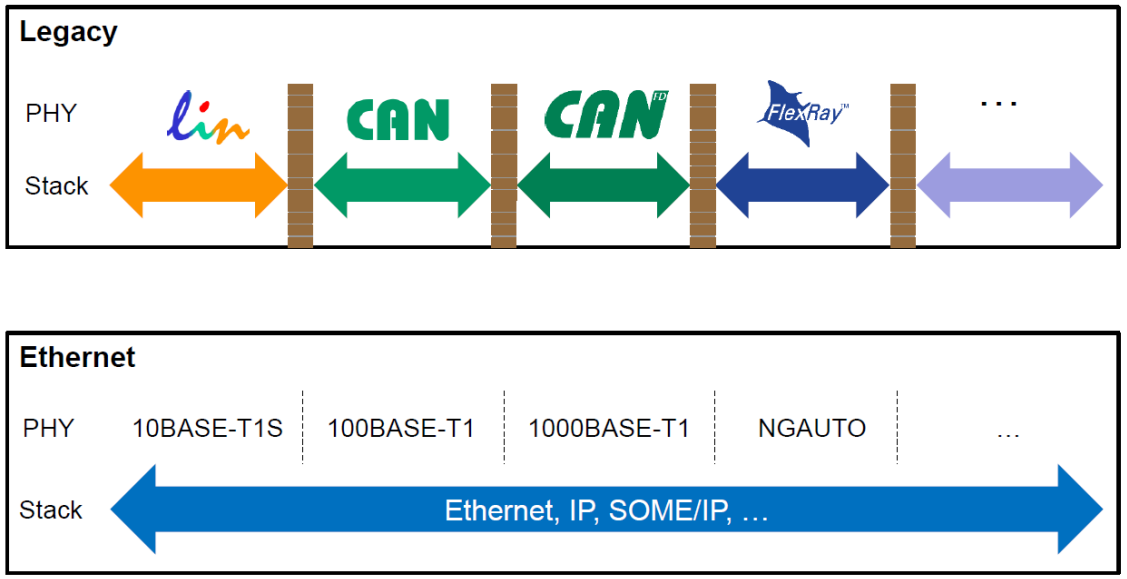
- Hands-free microphones
- Active speakers
- Noise vibration harshness
- Parking ECU
  - Radar
  - Ultrasonic
- Engine ECU
- Body ECU
- Active suspension
- Steering/braking system
- Charging units for electric cars
- Traffic sign recognition

80% of communication in car is below 10Mbps

Why 10Mbps Automotive Ethernet?

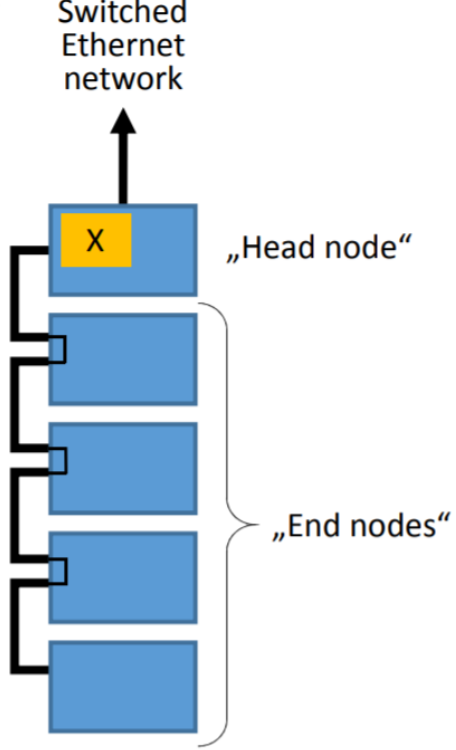
- **Standards:** 10BASE-T1S (802.3cg), 100BASE-T1 (802.3bw), 1000BASE-T1 (802.3bp) and Multigigabit Ethernet (802.3ch)
- Common Architecture with multiple speed option
- Unshielded cable, Full-duplex cable reduces cost by 80% and cable weight upto 30%
- Simplified Architecture

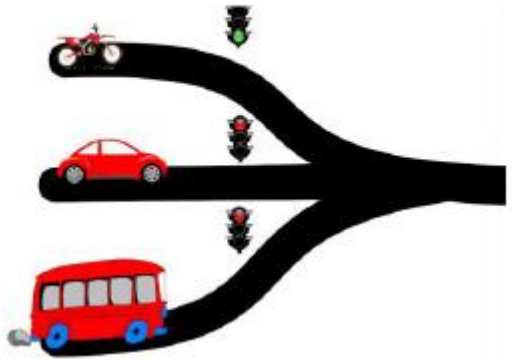
OSI	Automotive Ethernet
7 Application	Applications (HTTP, FTP, SMTP..)
6 Presentation	
5 Session	
4 Transport	TCP
3 Network	IP
2 Data Link	Network Access
1 Physical	10/100/1000/NGBASE-T1



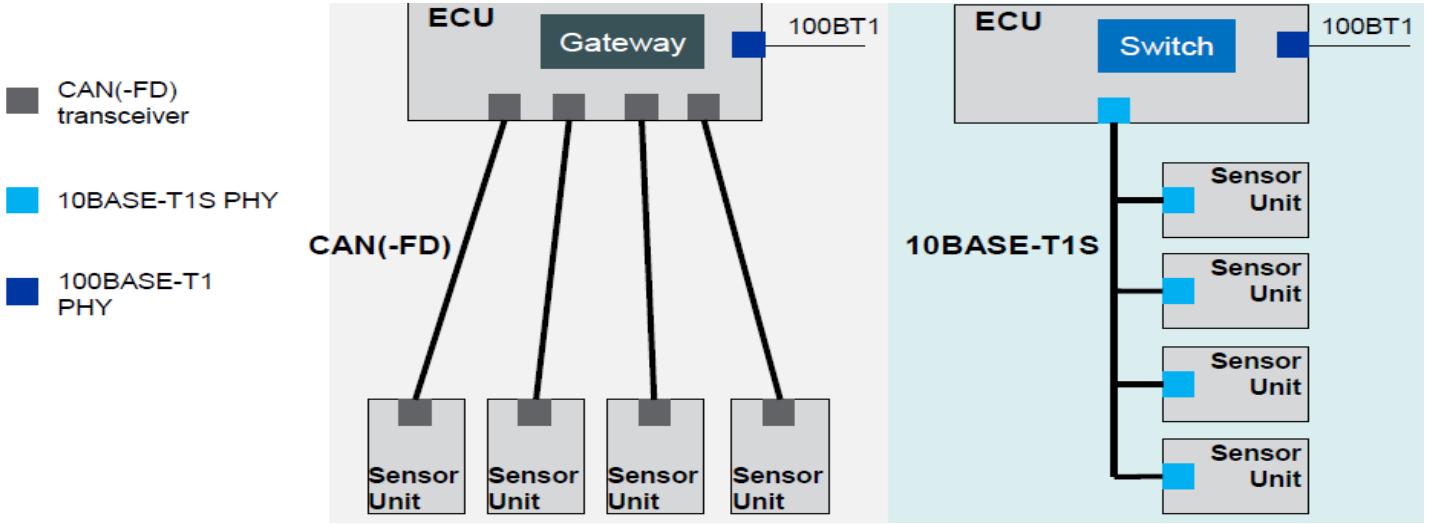
10BASE-T1S overview

- 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





Why 10Mbps Automotive Ethernet?

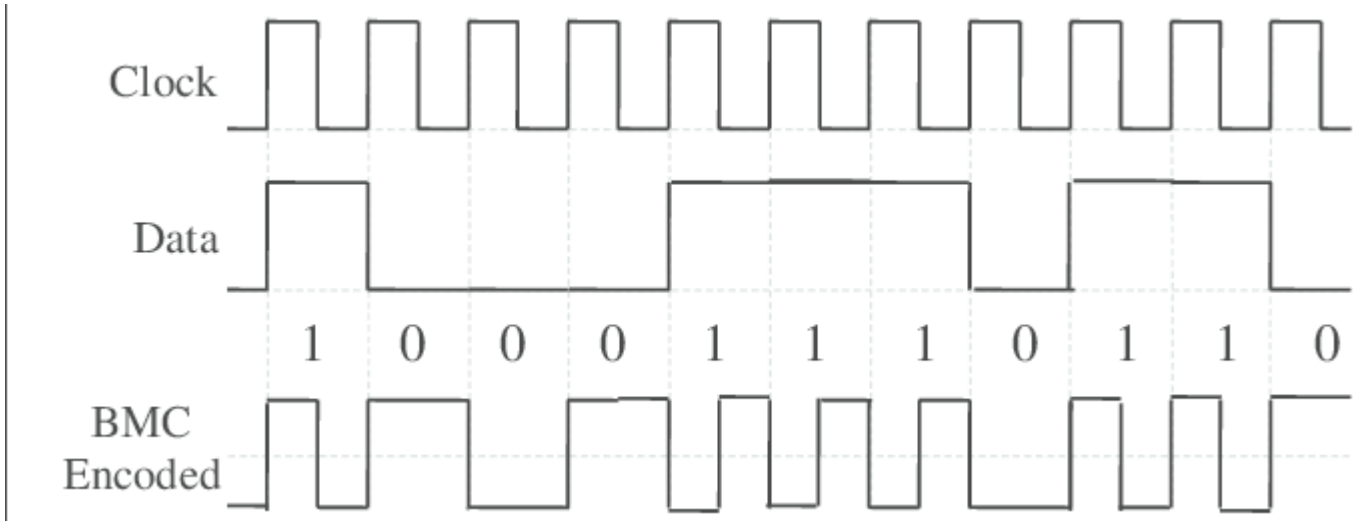


	CAN-FD	10BASE-T1S	Advantage
#PHYs	8	5	Fewer PHY required
#connectors @ECU	4	1	Less connector on ECU, less space
#Cable	4	1 Bus line	Less cabling, Extendibility, Scalability
Bandwidth	4*2Mbps	10Mbps	More bandwidth
Ethernet based network	No	Yes	Seamless integration into overall Ethernet system
Gateway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

Source: Microchip AEC, presentation

10BASE-T1S Encoding

- 4B/5B, Differential Manchester Encoding



Automotive Ethernet Compliance

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
Open Alliance TC1	Open Alliance TC12	Open Alliance TC14	Open Alliance TC15

TC8 ECU Specification

Automotive Ethernet PMA Test Specification

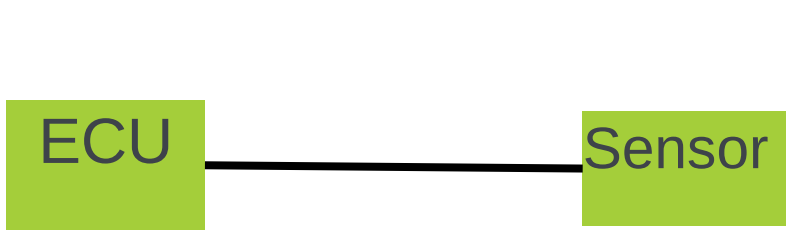
Test Name	Details/ Subtest	10BASE-T1S	100BASE-T1	1000BASE-T1	MultiGBASE-T1
Transmitter Output Droop	1) Positive Droop 2) Negative Droop	○	○	○	○
Transmitter Distortion			○	○	
Transmitter Linearity					○
Transmitter Timing Jitter in Master/Slave Mode	1) RMS/p2p MASTER Tx CLK 2) RMS/p2p SLAVE Tx CLK	○	○	○	○
Transmitter MDI Jitter		○	○	○	
Tx MDI Random Jitter (Master)	1) RMS/p2p MDI Jitter				○
Tx MDI Deterministic Jitter (Master)	1) pk-pk DJ 2) pk-pk EOJ				○
Transmitter Power Spectral Density	PSD, Power Level	○	○	○	○
Transmit Clock Frequency		○	○	○	○
Transmitter Peak differential output		○	○	○	○
MDI return Loss		○	○	○	○
MDI Mode conversion			○	○	
Common Mode emission			○		

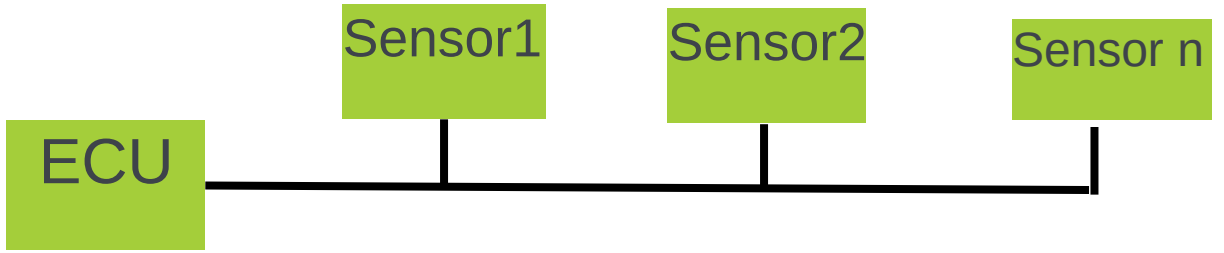
10BASE-T1S PMA Test Specification

- 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

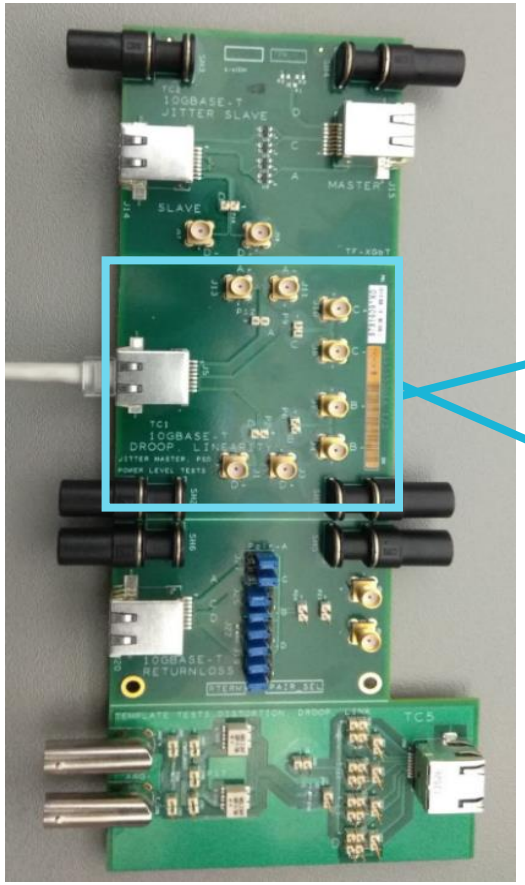
Mode of operation





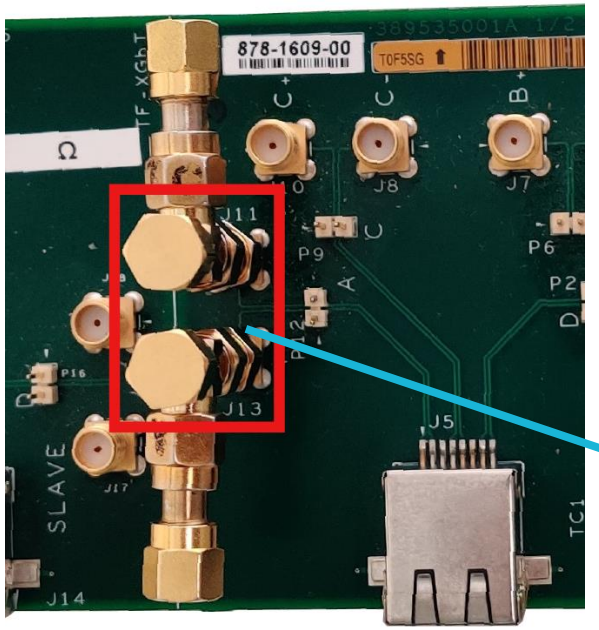
	Point to Point	Multidrop
Node	1 node	Upto 8 node, with 25cm stub
Cable length	15m reach	25m reach
Transmission load	100 ohm	50 ohm

Signal Access

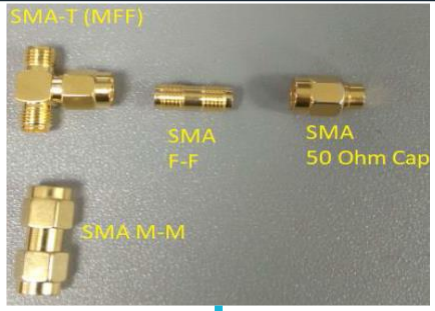


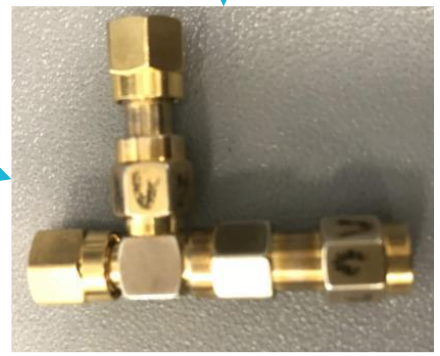
TF-XGbT Fixture

Point to Point test config (100ohm)



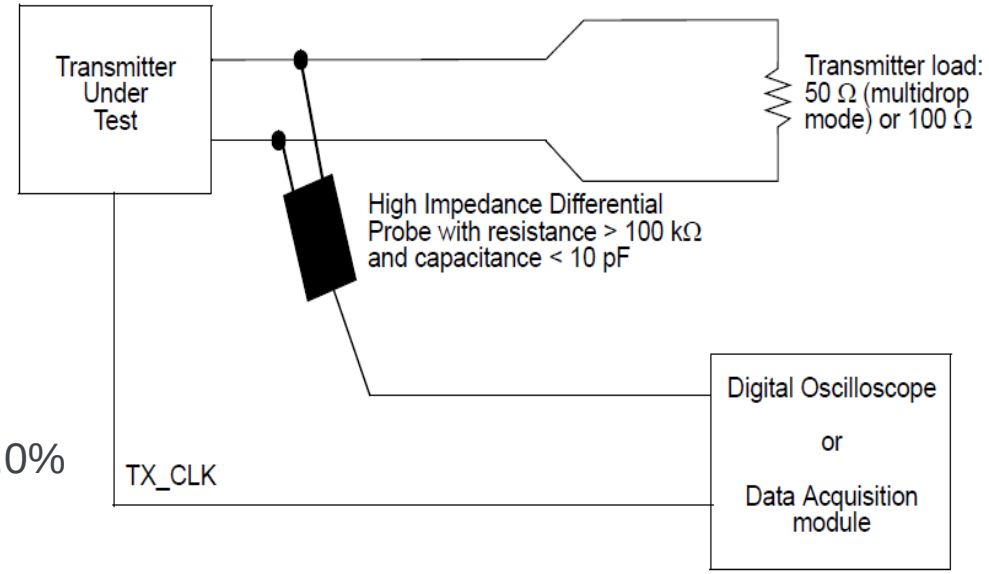
Multidrop test config (50 ohm)

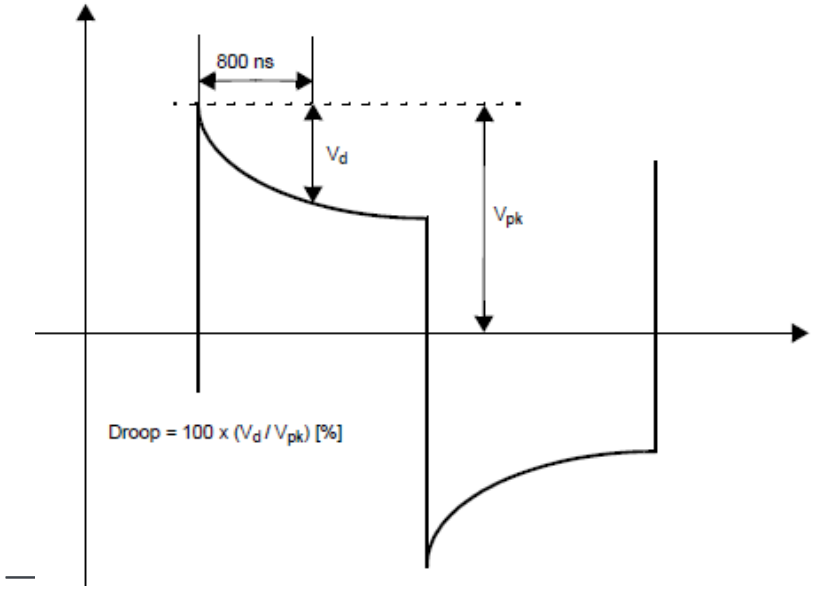




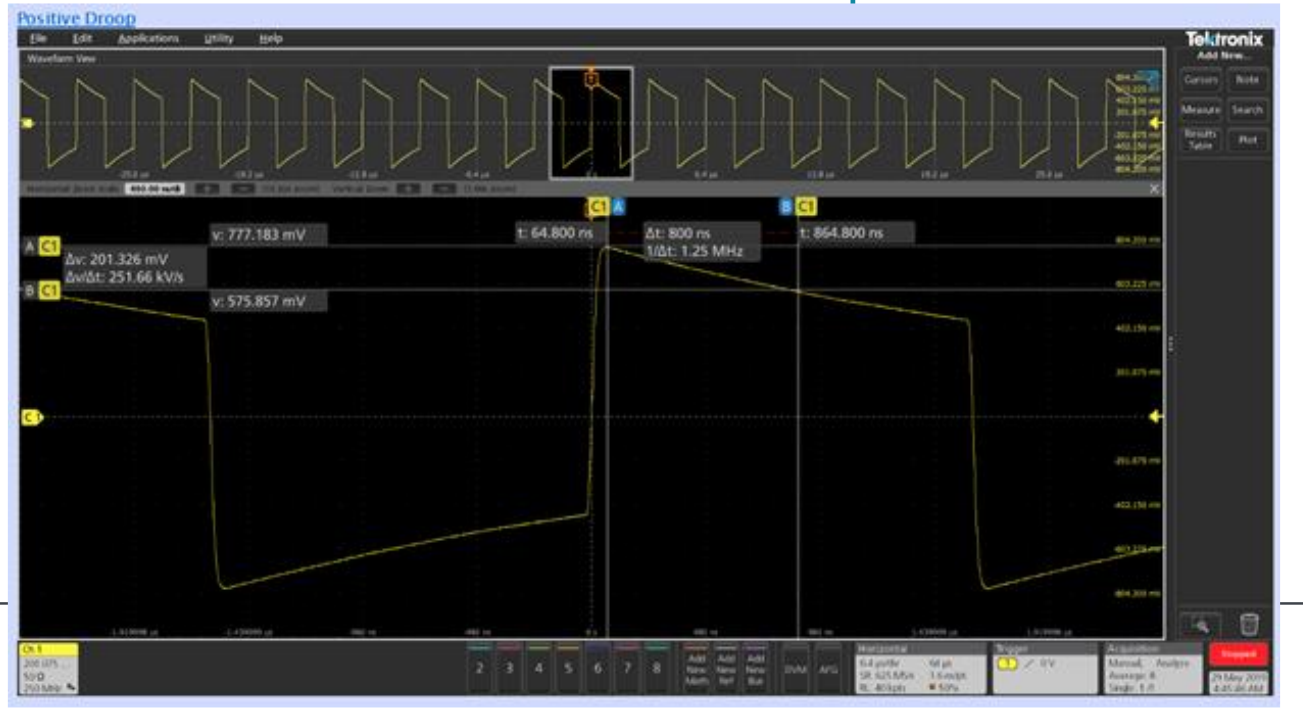
Maximum Droop Test

- Droop Measurement
  - Configure Test Mode 2
  - Transmit fifteen {+1} symbols followed by fifteen {–1} symbols continually
  - Value of 10bit 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)%



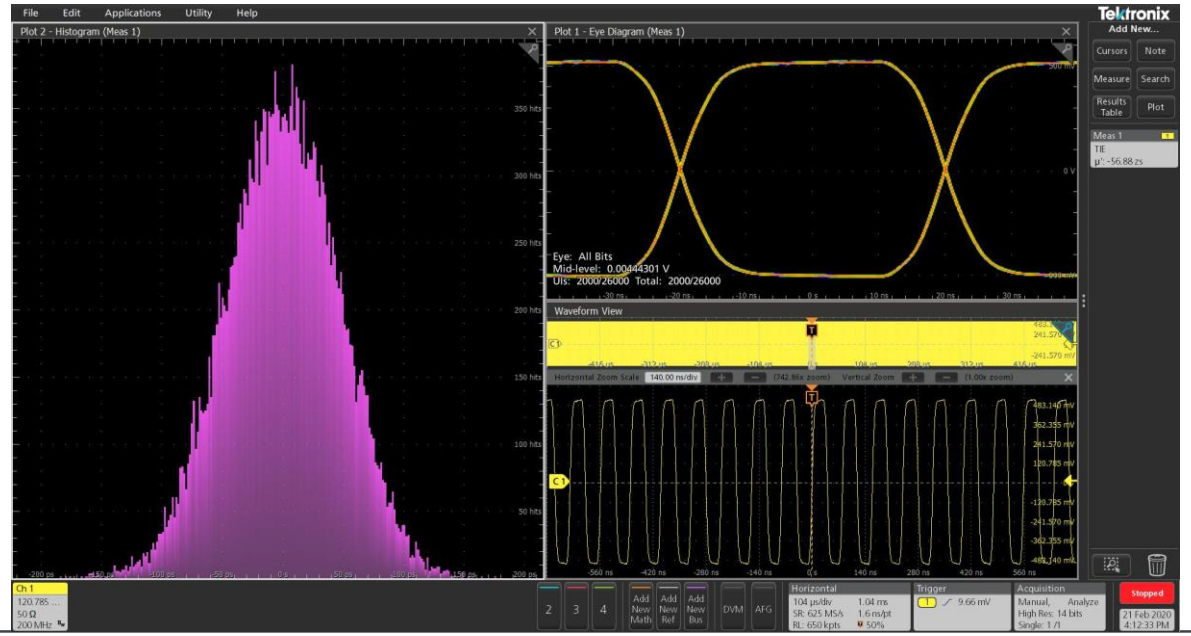


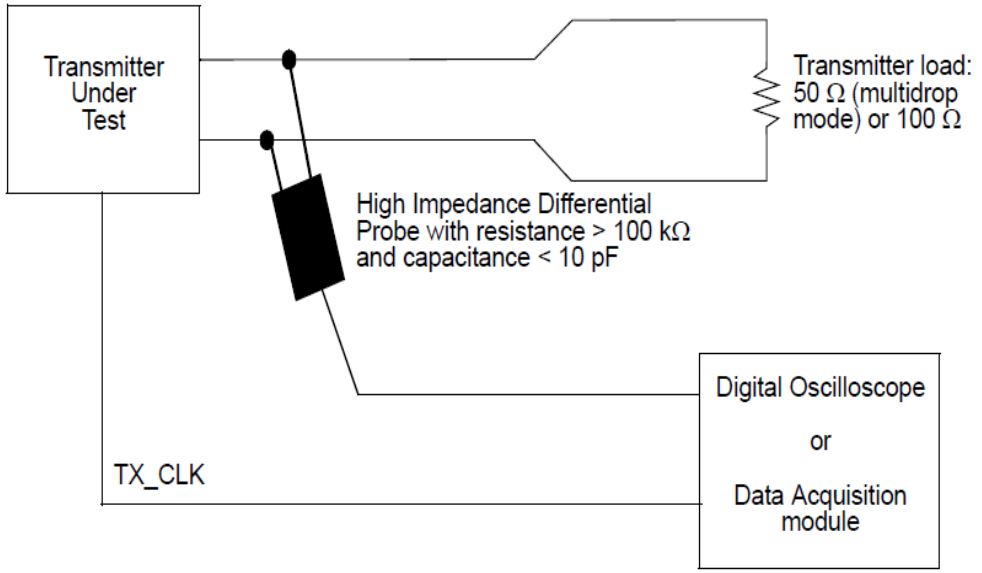
Droop



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)

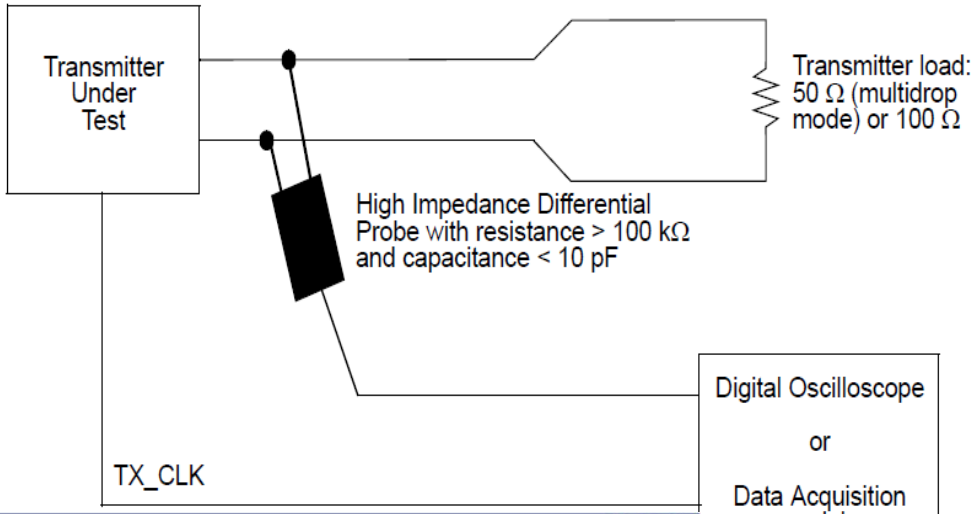


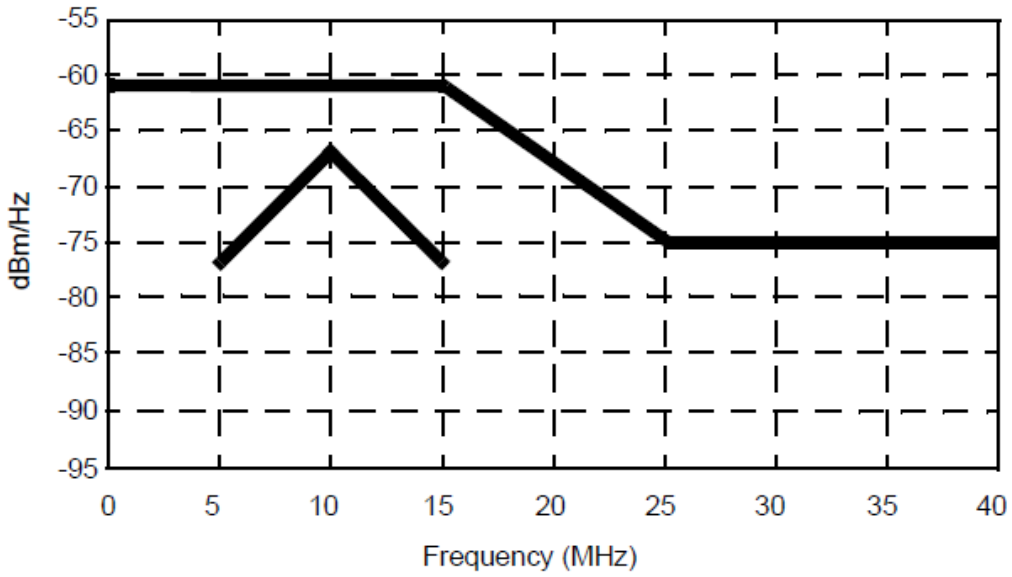


Clock Frequency & Jitter

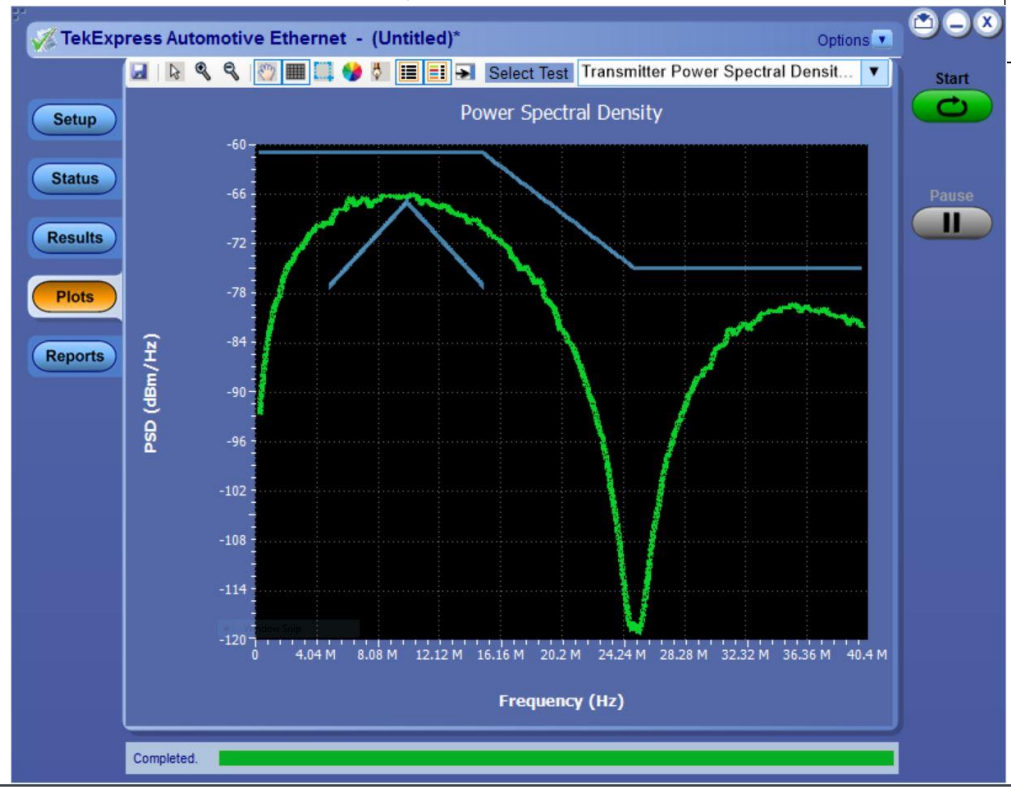
Power Spectral Density

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



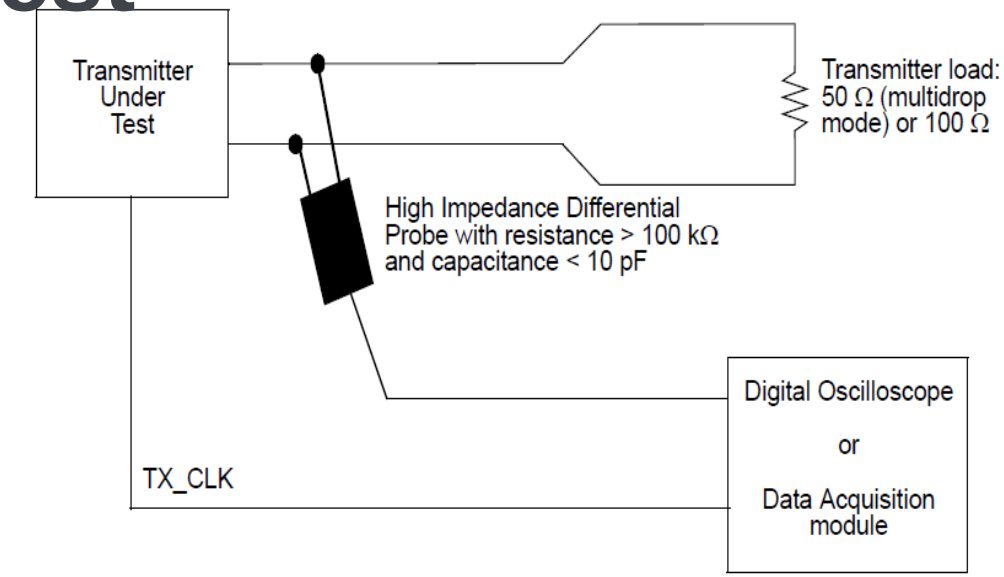


PSD Mask

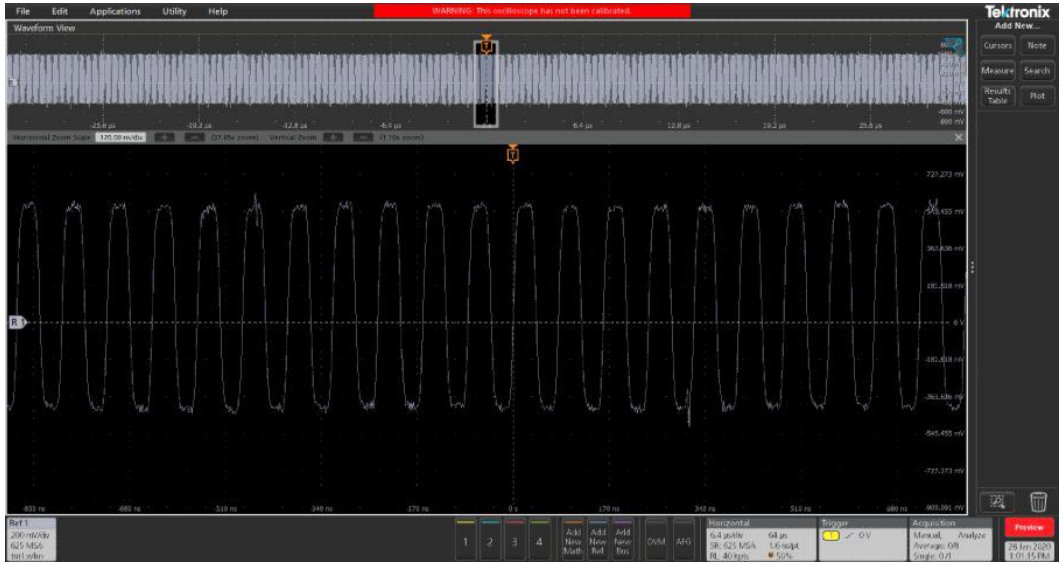


Tx Peak Differential Output Test

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

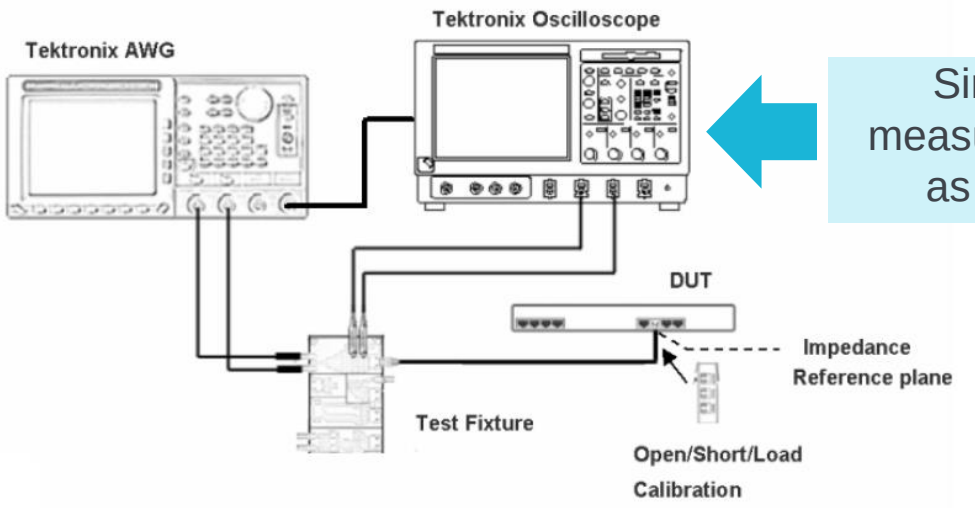


Differential Output



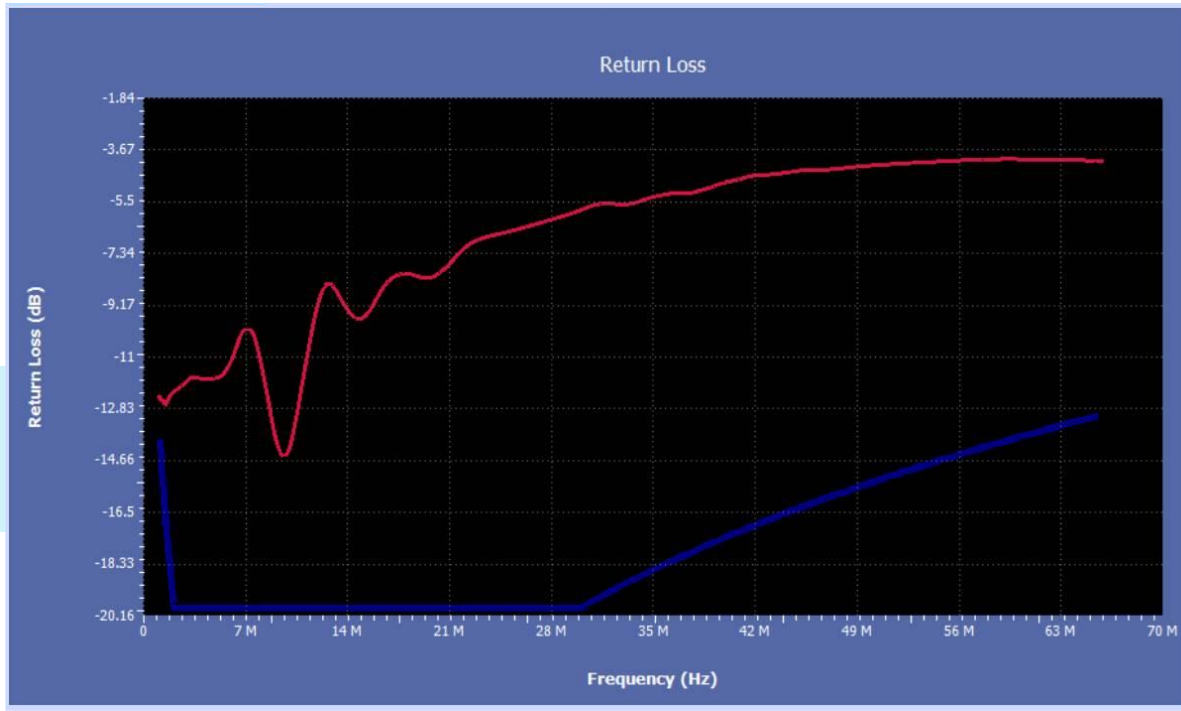
MDI (connector) Return Loss Test

- 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

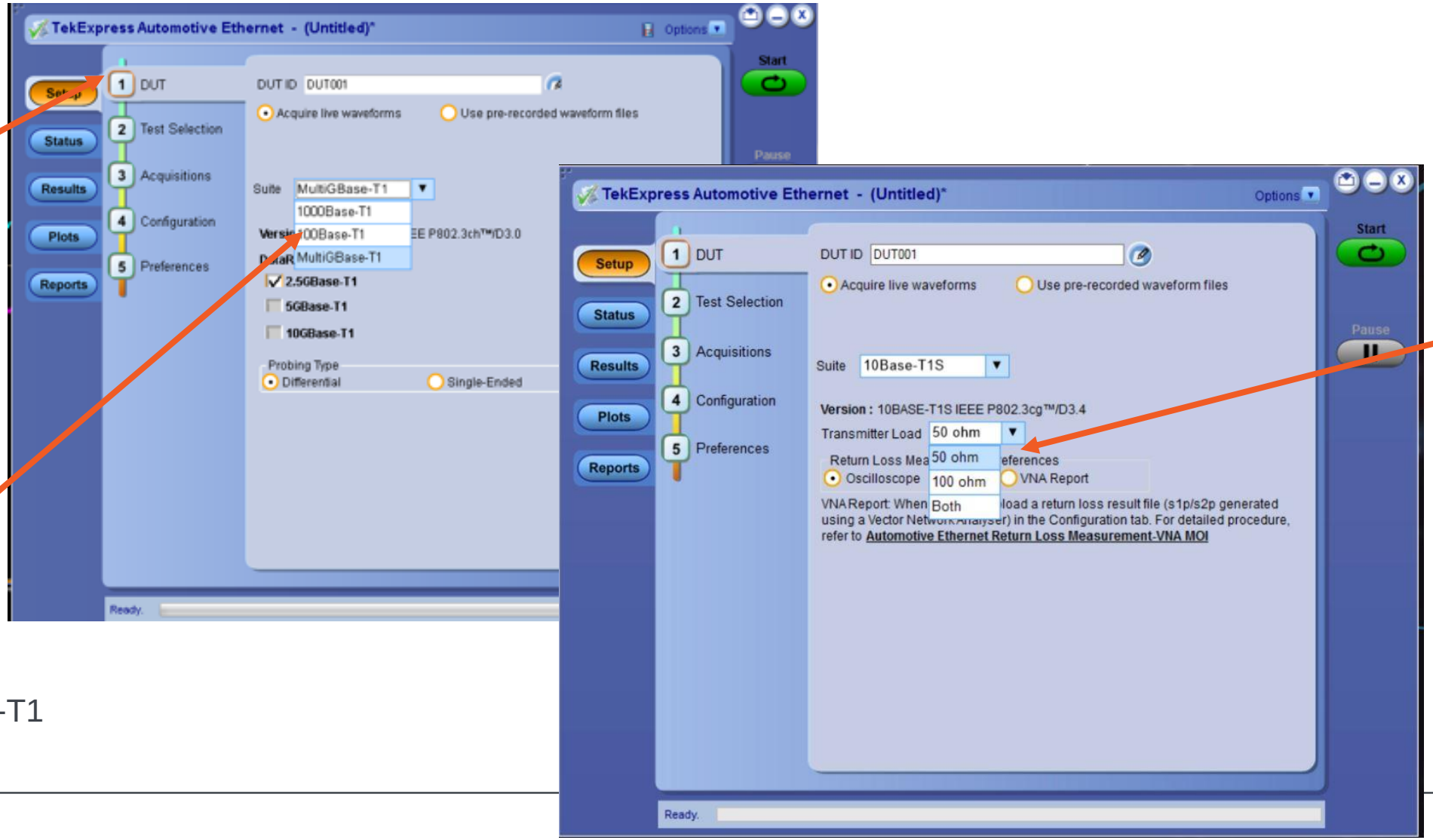
Return Loss using scope



10BASE-T1S Test solution

Automated Compliance

Wizard-based automation

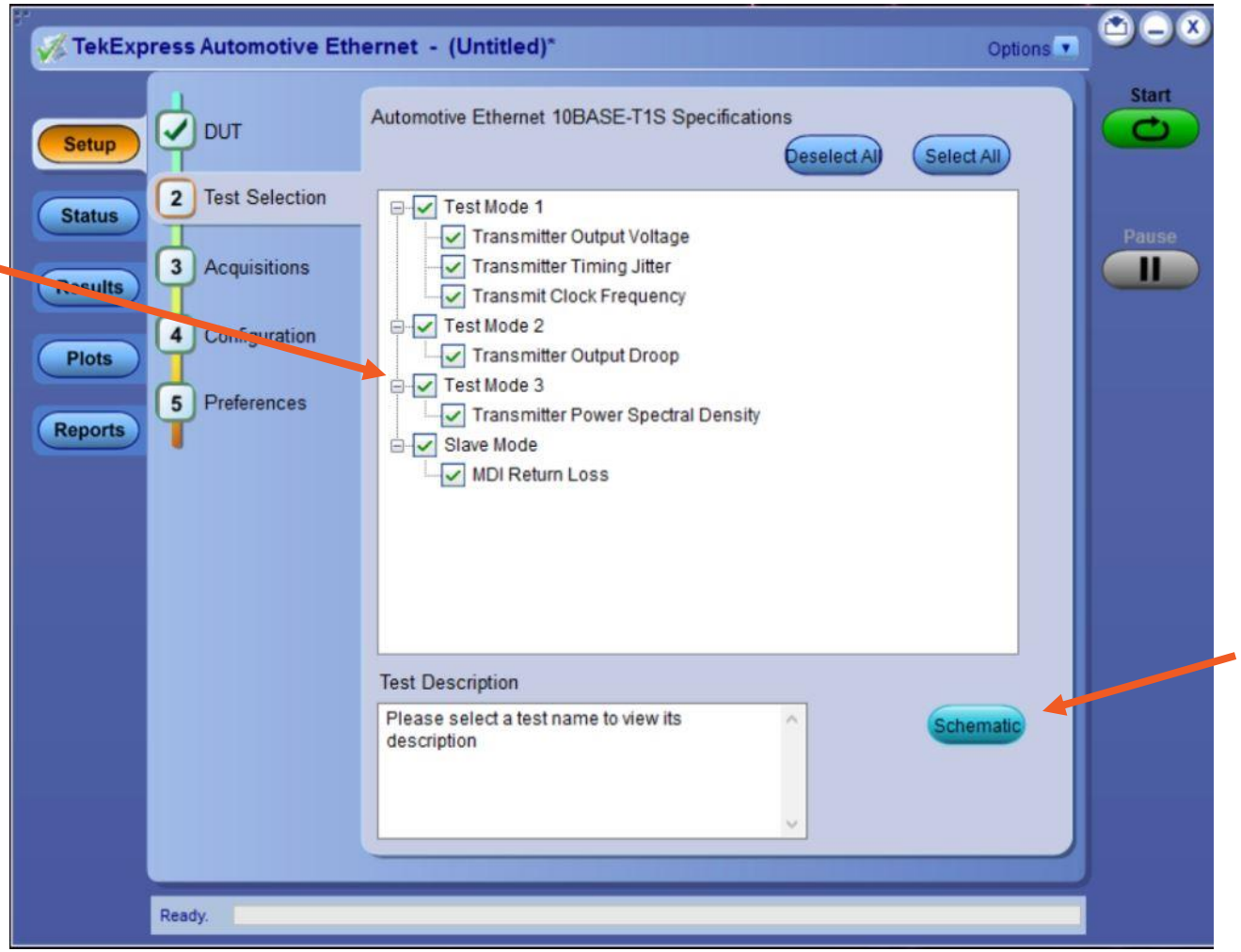


Point to Point or Multidrop

10BASE-T1S
100BASE-T1
1000BASE-T1
MultiGigaBASE-T1

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						

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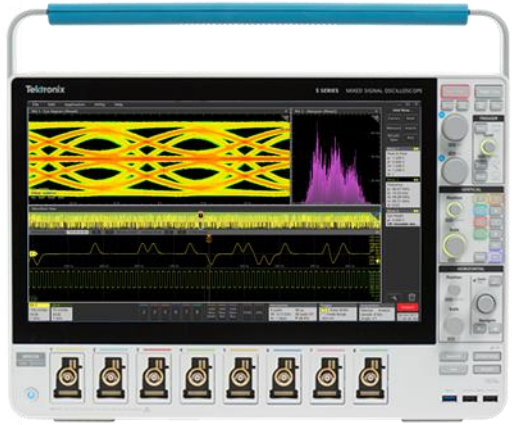
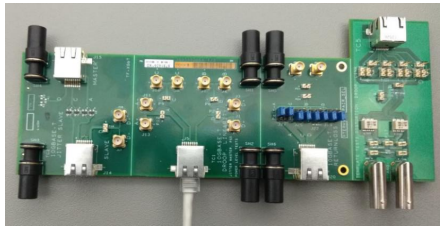
10BASE-T1S Compliance Solution

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





10BASE-T1S Test Demo

Tektronix

Thank you!