Tektronix

车载以太网的挑战及泰克测试解决方案

Ocean Yu

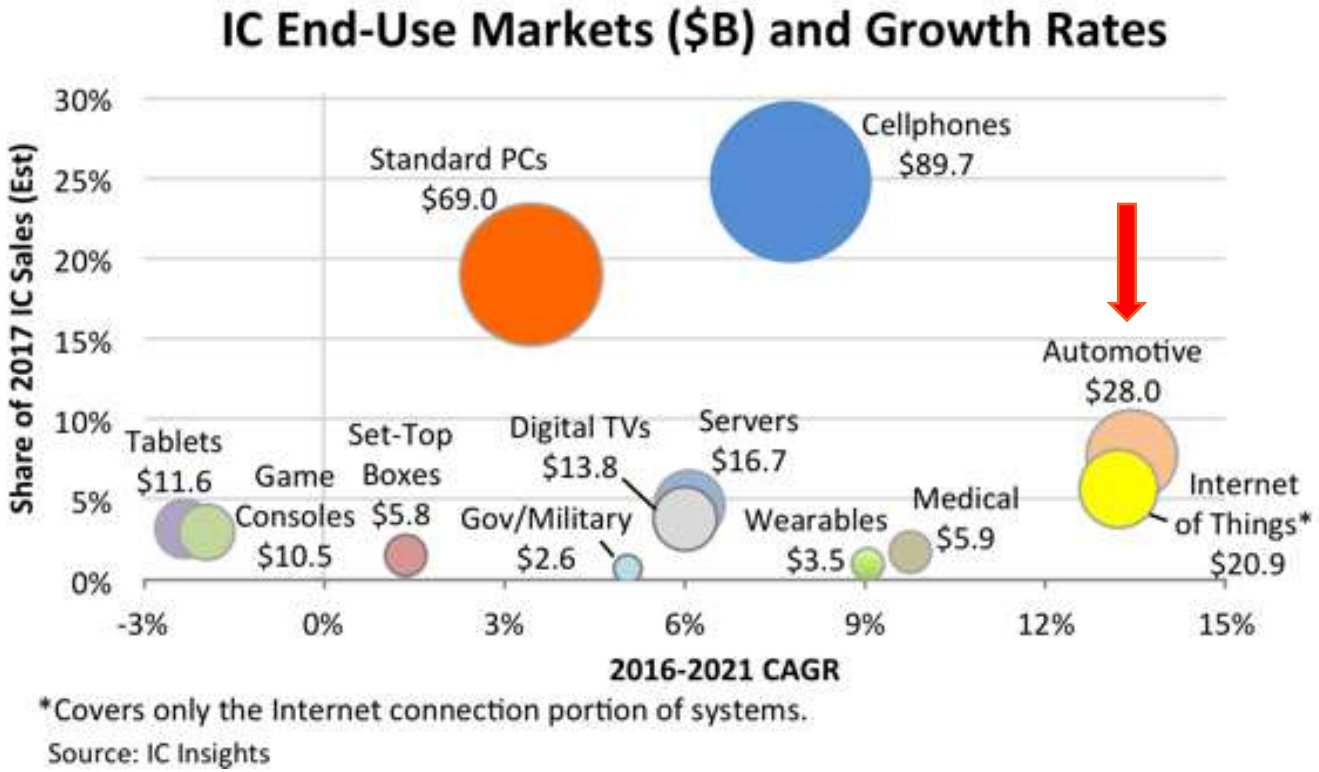
Automotive Trends

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



*Covers only the Internet connection portion of systems.

Source: IC Insights

Automotive Micro Drivers

Safety

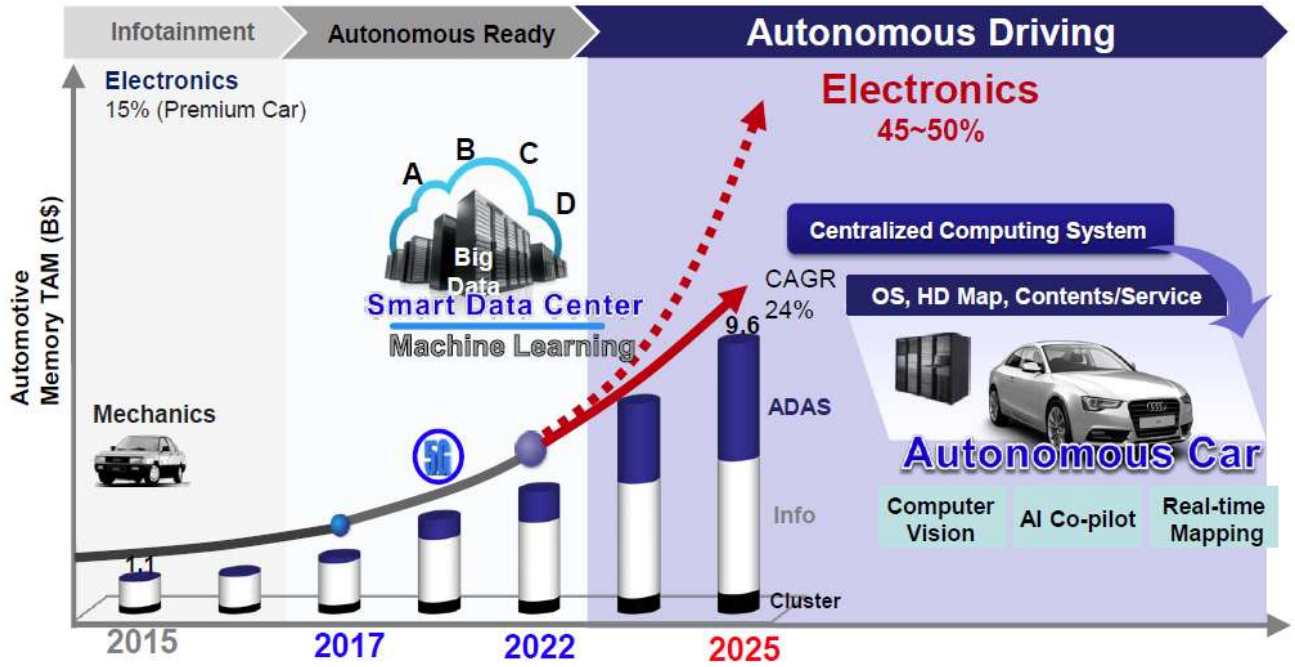
- Airbags, TPMS, backup camera
- NHTSA sets initiatives (*$4B over 19 years*) to accelerate ADAS

Fuel economy and emission

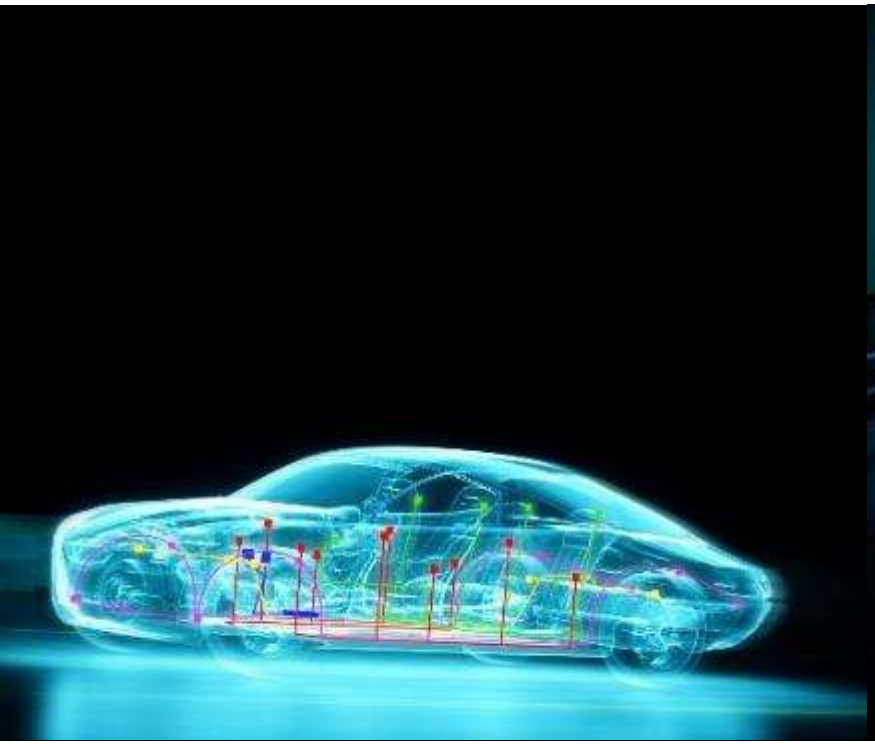
- Japan sets light commercial vehicle fuel standard to increase fuel economy by ***26%***
- U.S. sets ***45 – 50%*** reduction in CO2 emissions per mile by **2025**

Social & customer needs

- Connected car
- UBER, ZIP CAR, BMW Drivenow



Automotive Focus Areas

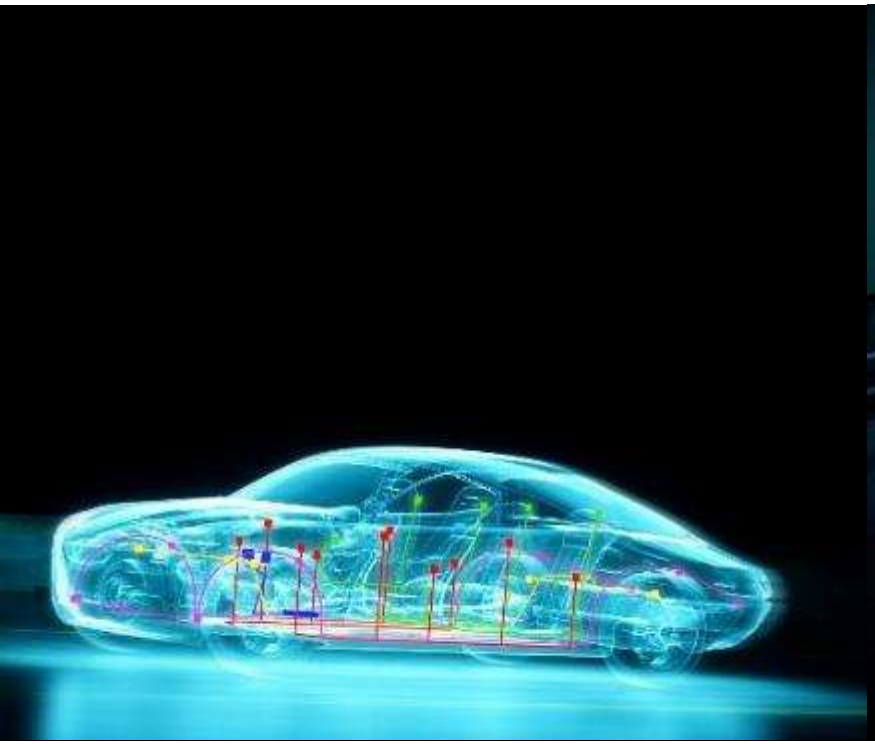


In-Vehicle Networking

Vehicle Sensors

Powertrain & Electrification

Automotive Focus Areas



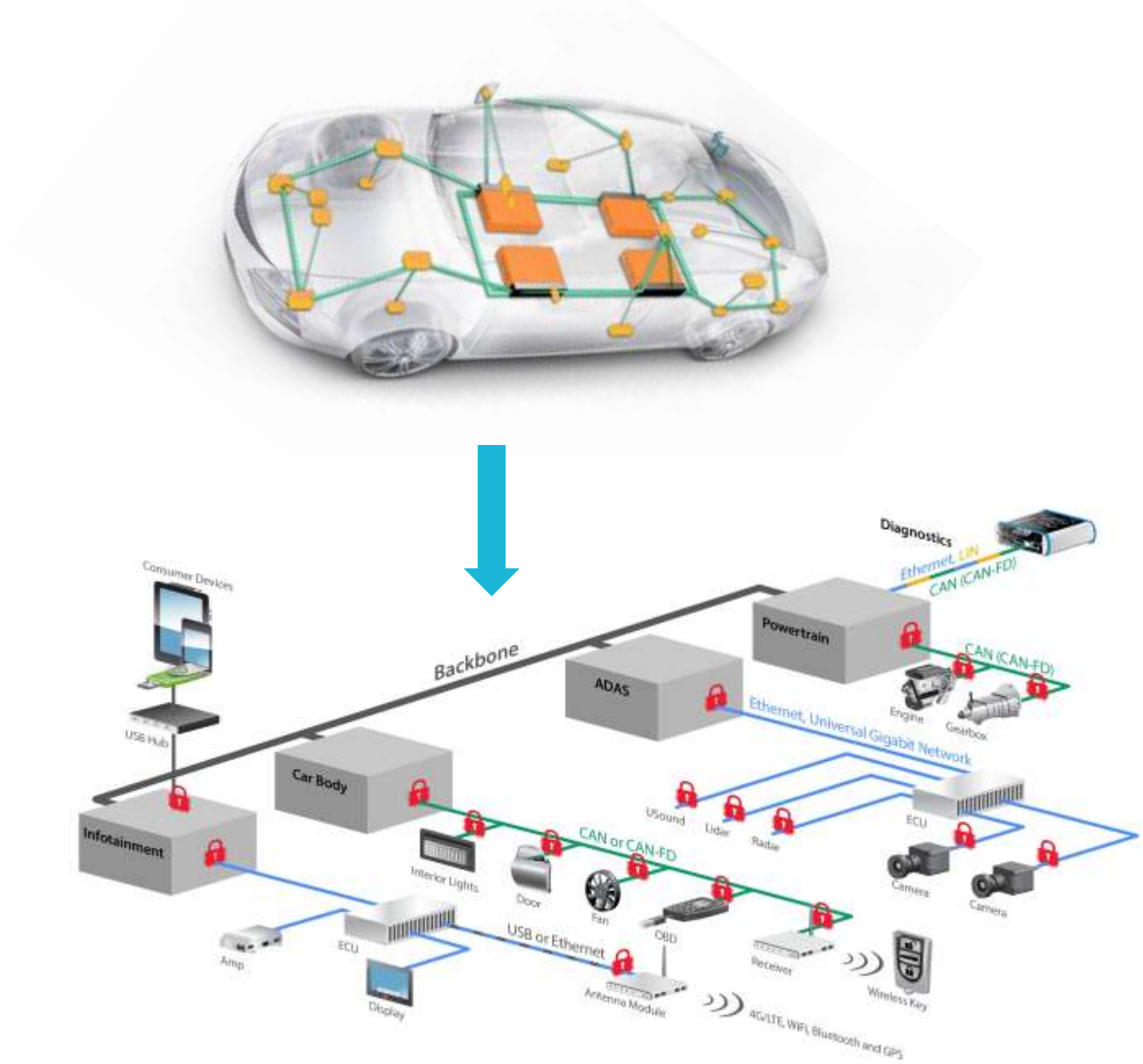
In-Vehicle Networking

Vehicle Sensors

Powertrain & Electrification

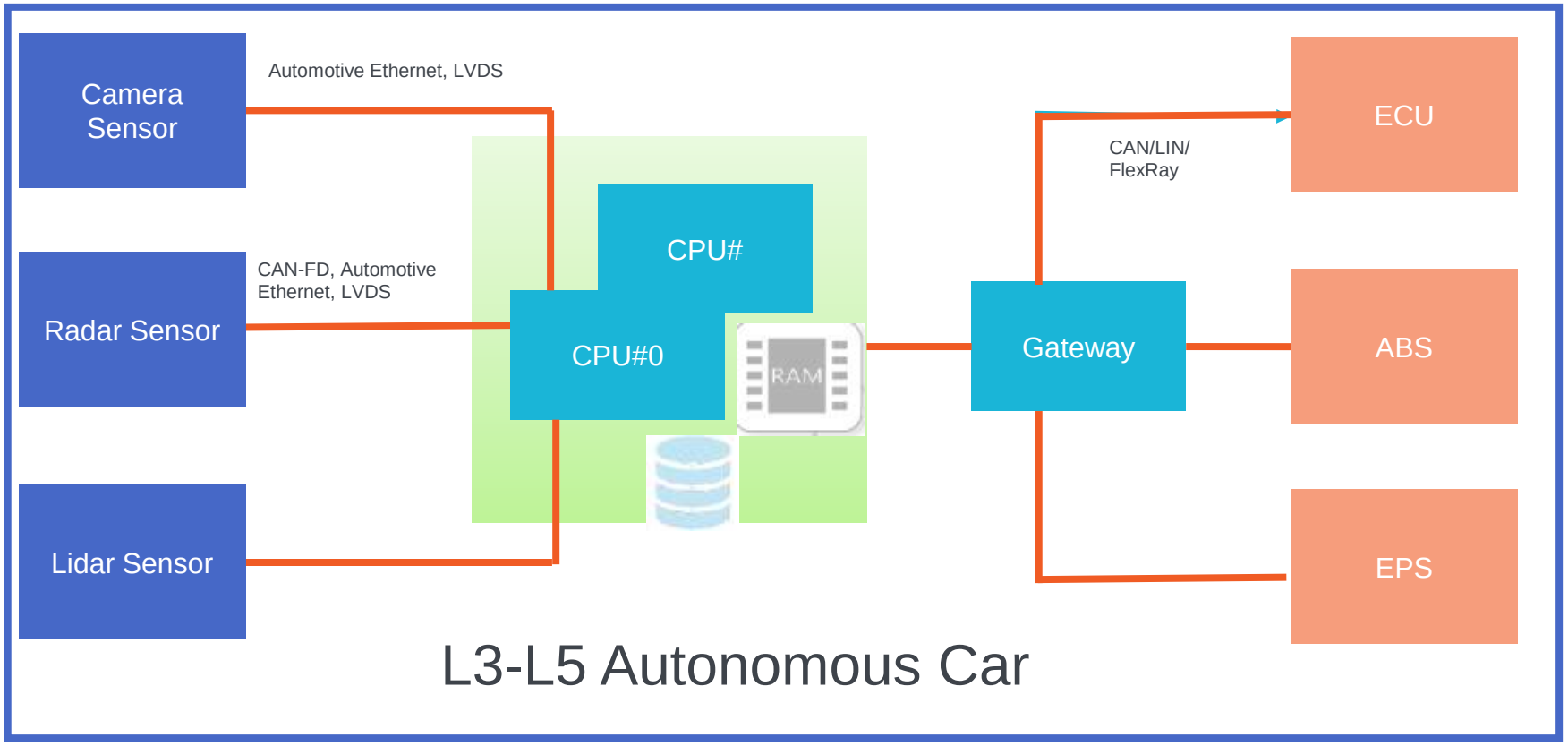
What is IVN?

- 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



Autonomous Car Block Diagram

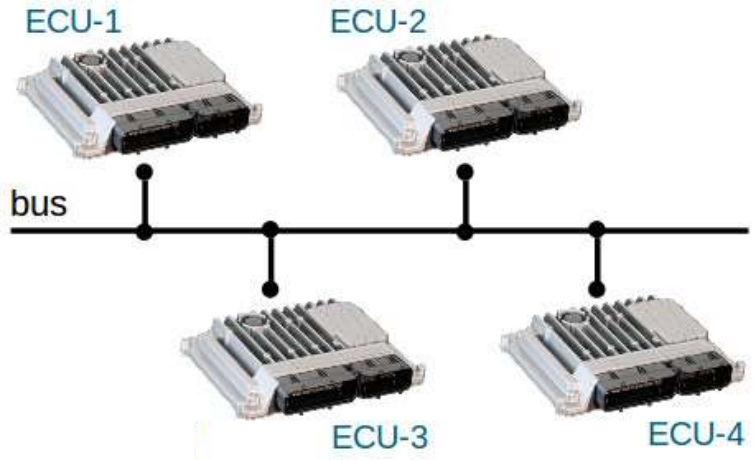
DOMAIN CONTROLLER

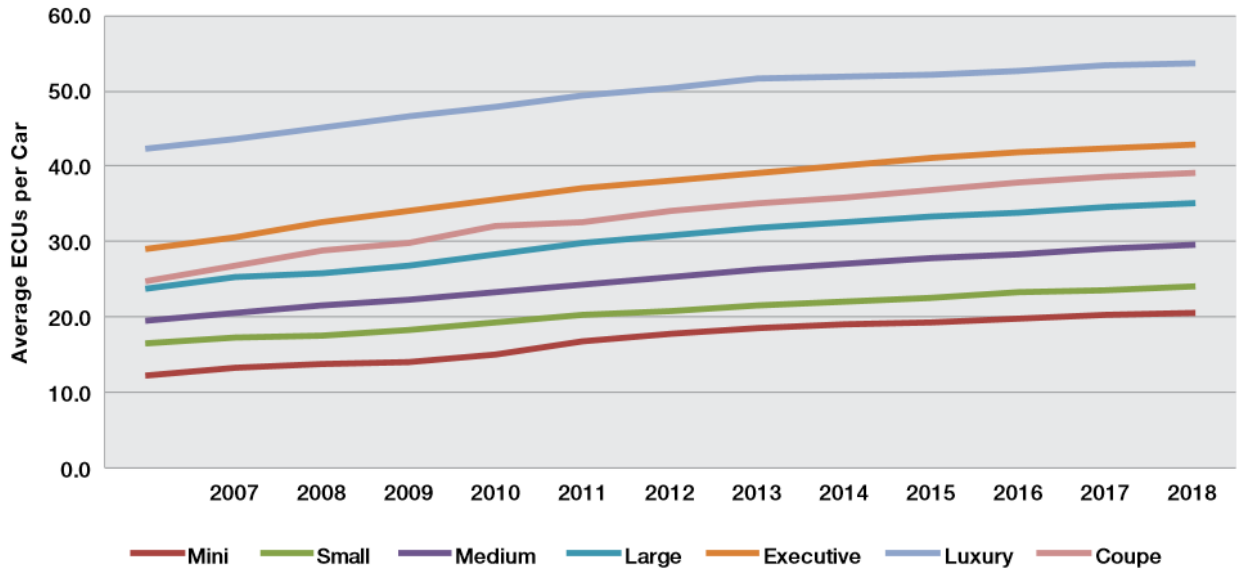


In-Vehicle Network

NETWORKS ON WHEELS

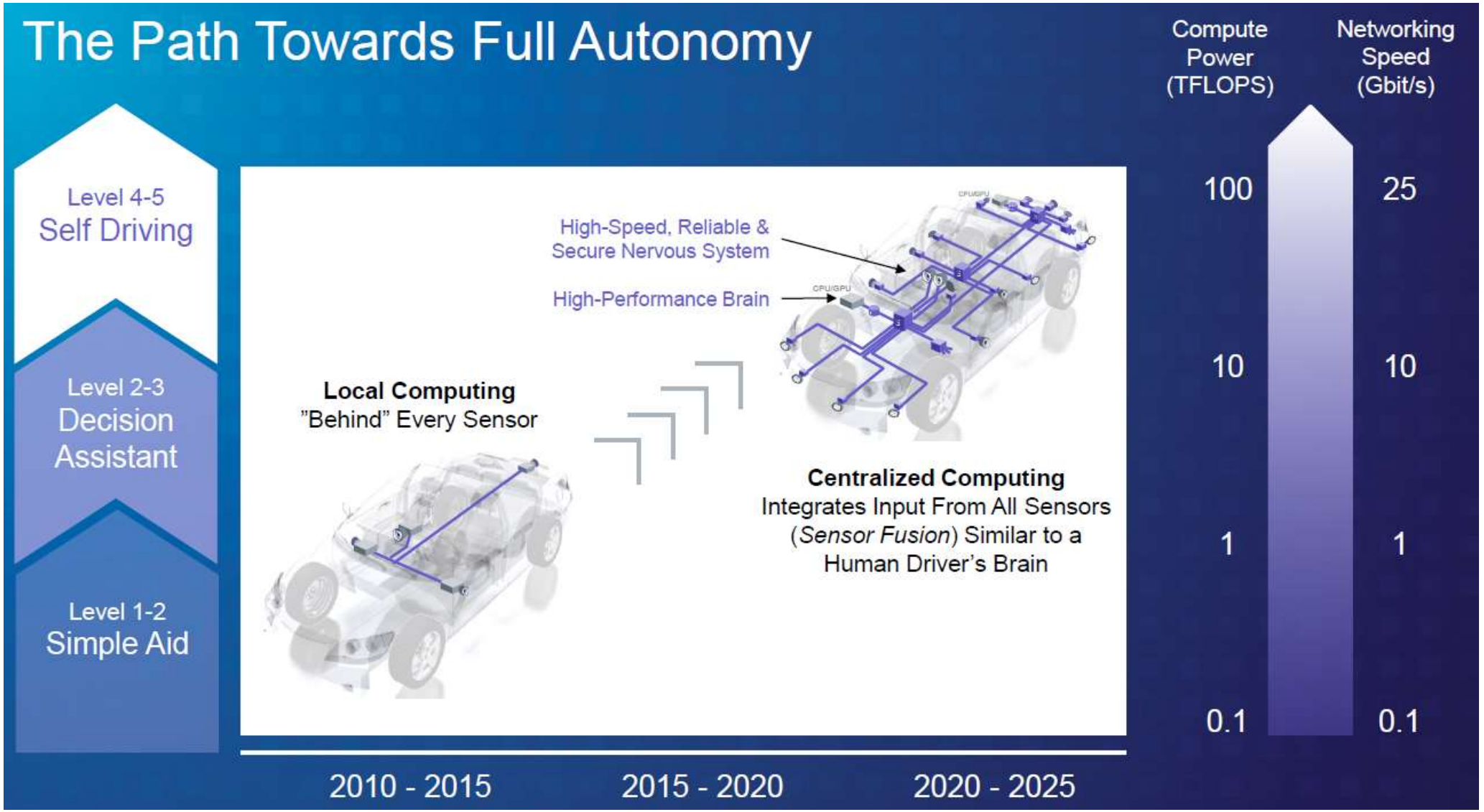
- Ecus communicate with each other over in-vehicle network (*IVN*)
- On average there are **30-40 ecus** in luxury car
- Each ECU have **at least one** IVN node
- Requirements
  - Low cost, low weight, low power
  - Reliable
  - Withstand harsh environment
  - High speed, low latency





*Strategy Analytics

IVN Datarate



In-Vehicle Network standards

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 100M-1G	100/1000BASE-T1	100/1000BASE-T1, Apix, GVIF, GMSL	100/1000BASE-T1	
High Speed Sensor 1G-3G	FPD-Link, LVDS, NGBASE-T1, A-PHY, 25G Automotive Ethernet	HDBase-T, A-PHY, LVDS		

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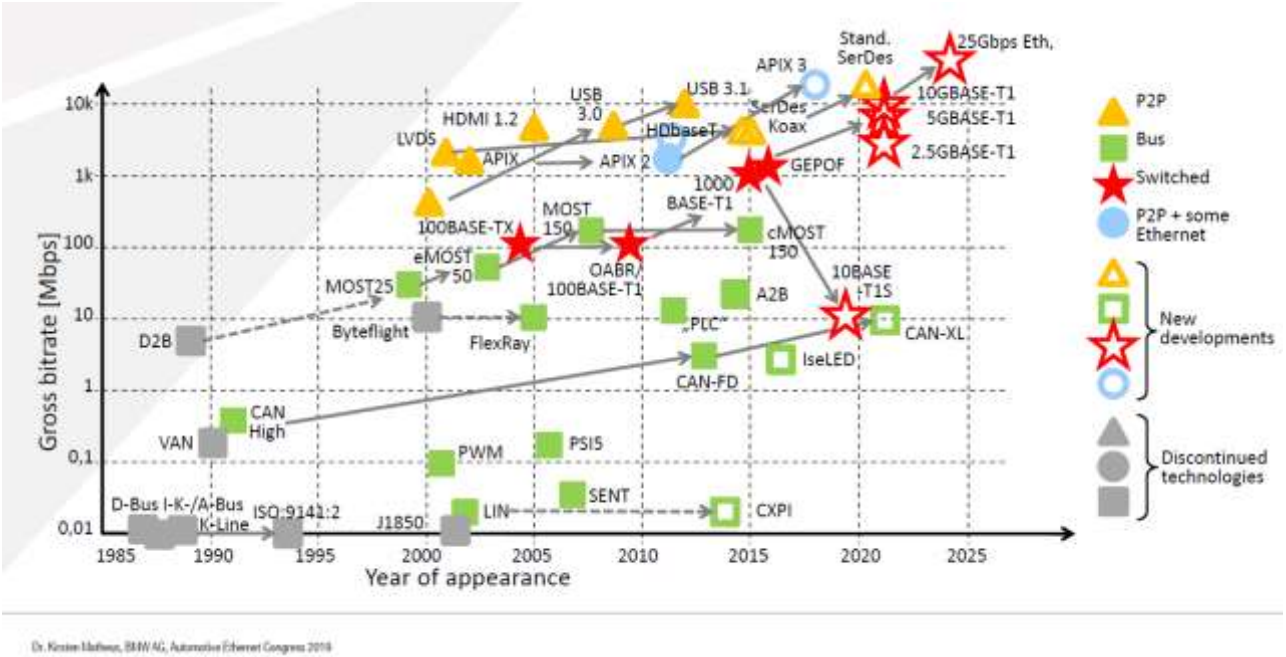
IVN Serial Standards

Trends

- Standardization
- Modulated signals (*PAM3 / PAM4 / PAM16*)
- Power over Dataline (PoDL)
- Symmetric and Asymmetric communication



Standards

- 100/1000BASE-T1 (*IEEE 100/1000Mbps*)
- 10BASE-T1S (*IEEE 10Mbps*)
- 2.5G/5G/10GBASE-T1 (*IEEE 2.5/5/10Gbps*)
- A-PHY (*MIPI 12Gbps*)
- HDBASE-T (*1-6Gbps*)
- Auto-Serdes (13Gbps PAM4)
- Optical Automotive Ethernet

- *Source: Dr. Kirsten Matheus, AEC-2019 presentation

Automotive Ethernet IEEE Standards

FROM DATACENTER TO PASSENGER CAR

802.3cg

10BASE-T1, 10Mbps,
(**S-15m, L- up to 1km**)

802.3bw

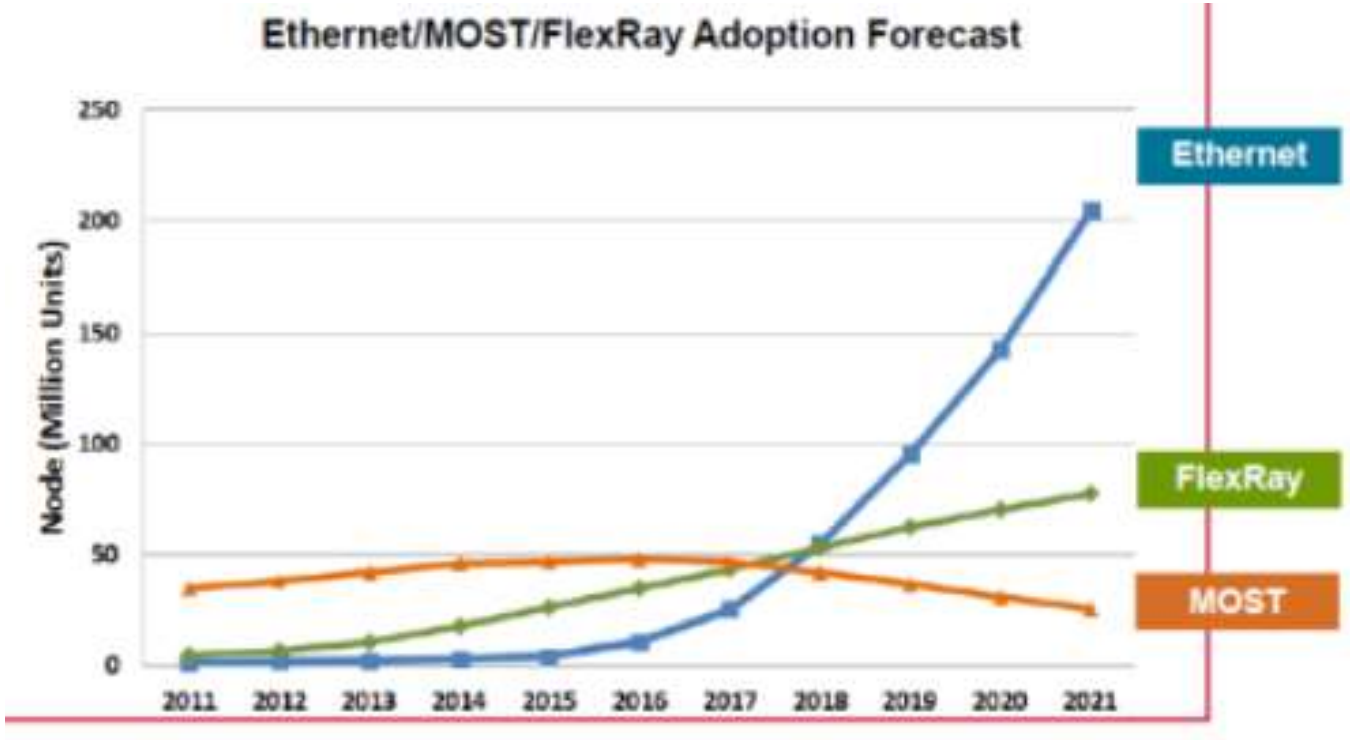
100BASE-T1, 100Mbps,
PAM3 Modulation (15m)

802.3bp

1000BASE-T1, 1Gbps,
PAM3 Modulation (15m)

802.3ch

10GBASE-T1, 2.5/5/10Gbps

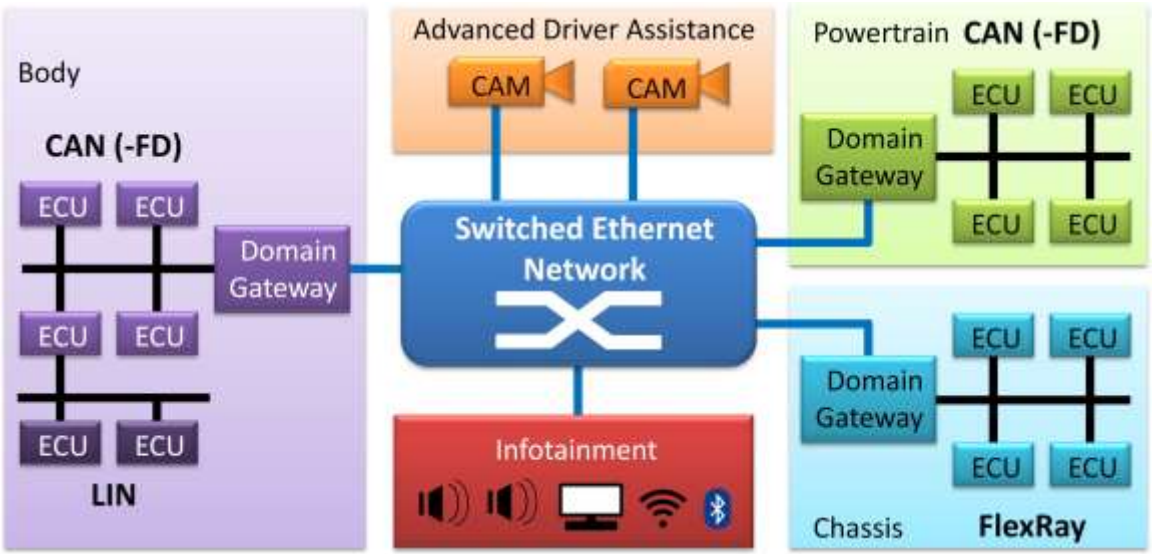


Ethernet adoption forecast

* High-speed automotive bus demand estimates 2015 by Strategy Analytics

Why Automotive Ethernet?

- Enables support for high data rate applications (*ADAS, IVI*)
  - Low latency for ADAS (*<250us*)
- Well-proven technology, customized for automotive needs
- Co-exists with lower speed buses (*CAN-FD, LIN, etc.*)
- Unshielded single twisted pair cabling designed for automotive environment and lower cost
- Can reuse existing application layer ethernet stack
- Uses PAM3 signaling to meet EMI/EMC requirement



Tektronix standards Participation

- Partha:
  - Chairperson, MIPI Test working group
  - IEEE member Multigigabit Ethernet
  - Open Alliance participants
- Ramesh:
  - IEEE member Multigigabit Ethernet
  - HDBaseT contributor
- Pavel:
  - IEEE member Optical Ethernet and 400G Ethernet

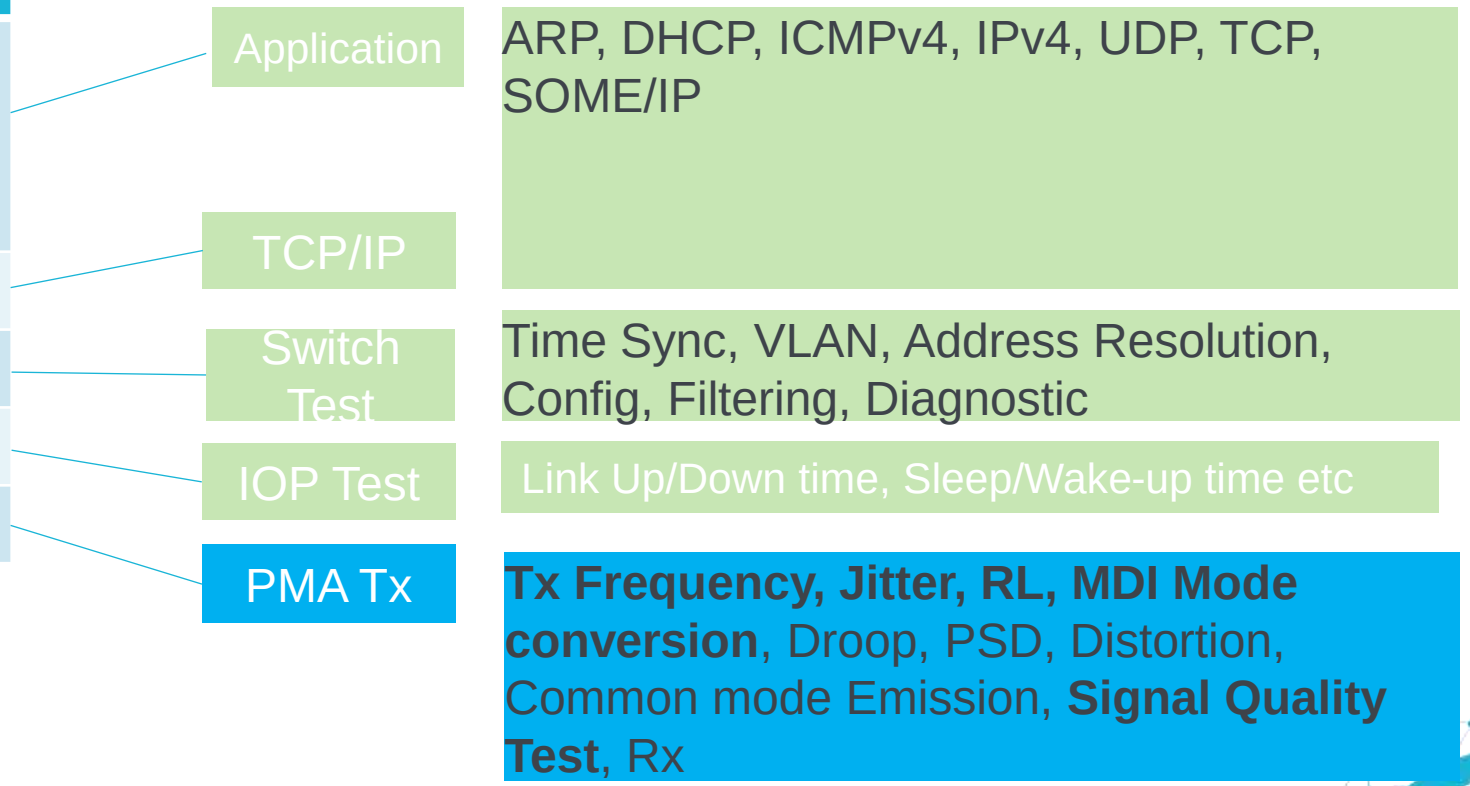
Automotive Ethernet Compliance

Ensuring Performance And Interoperability

Ethernet: TC8 & Its Test Requirements

TC8 = Technical Committee 8
(governing body for compliance standards)

OSI	Automotive Ethernet
7. Application	Application
6. Presentation	
5. Session	
4. Transport	TCP
3. Network	IP
2. Datalink	Network Access
1. Physical	100/1000BASE-T1



***bold** indicates mandatory tests

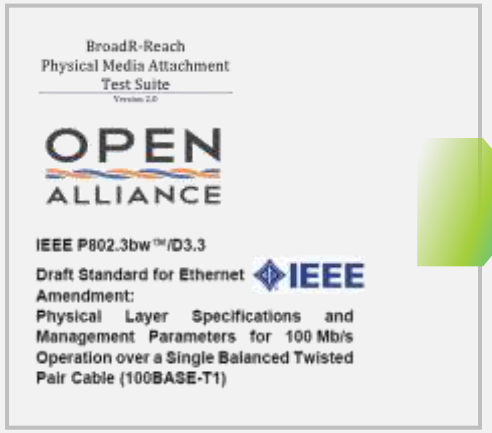
Automotive Ethernet Test Requirement

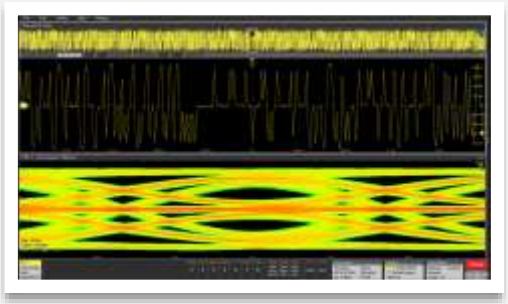
Multiple testing needs including physical layer (PMA) transceiver, receiver, communication channel, and EMC

- PHY Media Attachment Test suit
- EMC test for common mode chock
- Interop test
- PHY control test
- Physical coding sublayer test
- Communication channel test
- Open sleep / wakeup test
- EMC test for trans receiver
- EMC spec for ESD suppression devices

Automotive Ethernet PMA Compliance

- 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 (*master / slave*)
  - MDI output jitter
  - Distortion
  - Power spectral density
  - Clock frequency
  - MDI return loss
  - Peak differential output
- PAM3 signaling





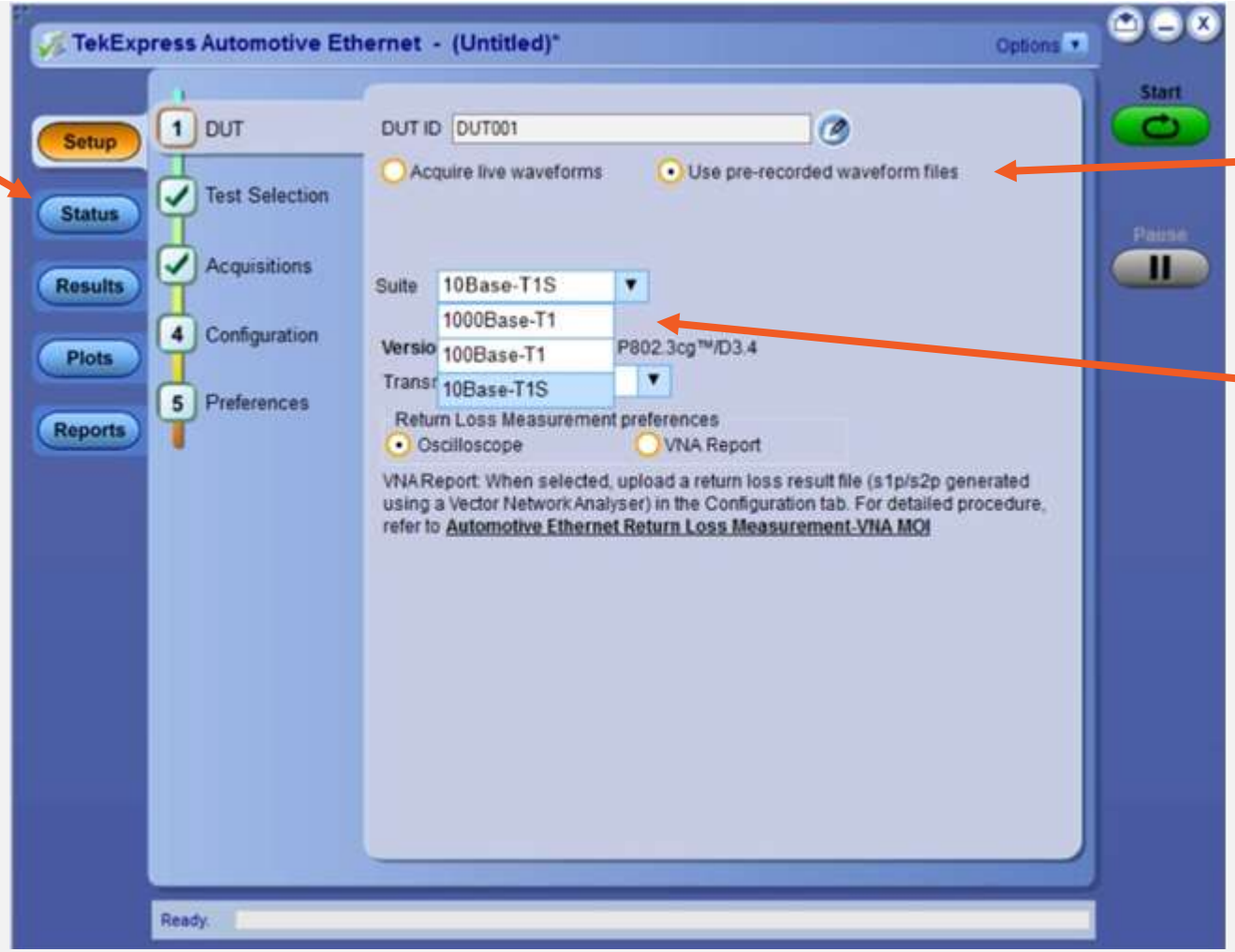
Group 1: Electrical Measurements	
Maximum Transmitter Output Droop	Test 5.1.1
Transmitter Distortion	Test 5.1.2
Transmitter Timing Jitter (MASTER, SLAVE)	Test 5.1.3
Transmitter Power Spectral Density	Test 5.1.4
Transmit Clock Frequency	Test 5.1.5
MDI Return Loss	Test 5.1.6
MDI Mode Conversion Loss	Test 5.1.7
Transmitter Peak Differential Output	Test 5.1.8

1000BASET1 Measurement	Spec ID
Tx Droop Measurement	5.3.1
Tx Distortion Measurement	5.3.2
Tx_TCLK125 Jitter	5.3.3
Tx_TCLK125 Jitter	5.3.3
MDI_output_Jitter	5.3.3
Tx PSD	5.3.4
Tx Peak Diff output	5.3.5
Tx Clock Frequency	5.3.6
MDI Return Loss (S11)	7.2.1
MDI Mode Conversion loss	7.2.2

* PMA: Physical Media Attachment

Automated Compliance

Wizard-based automation

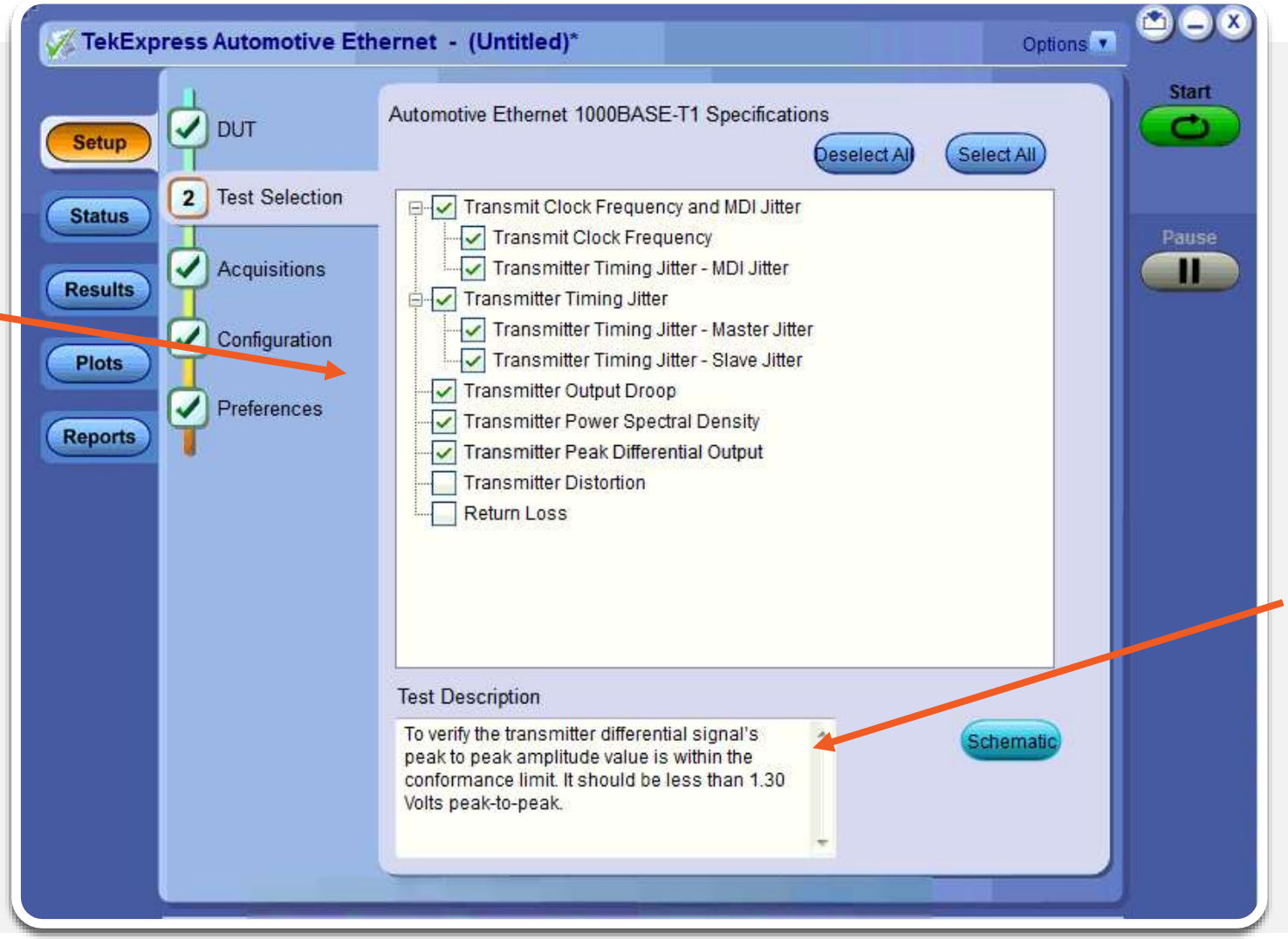


Live or offline testing

Latest 100 / 1000BASE-T1 and 10Base-T1 support

Test Selection

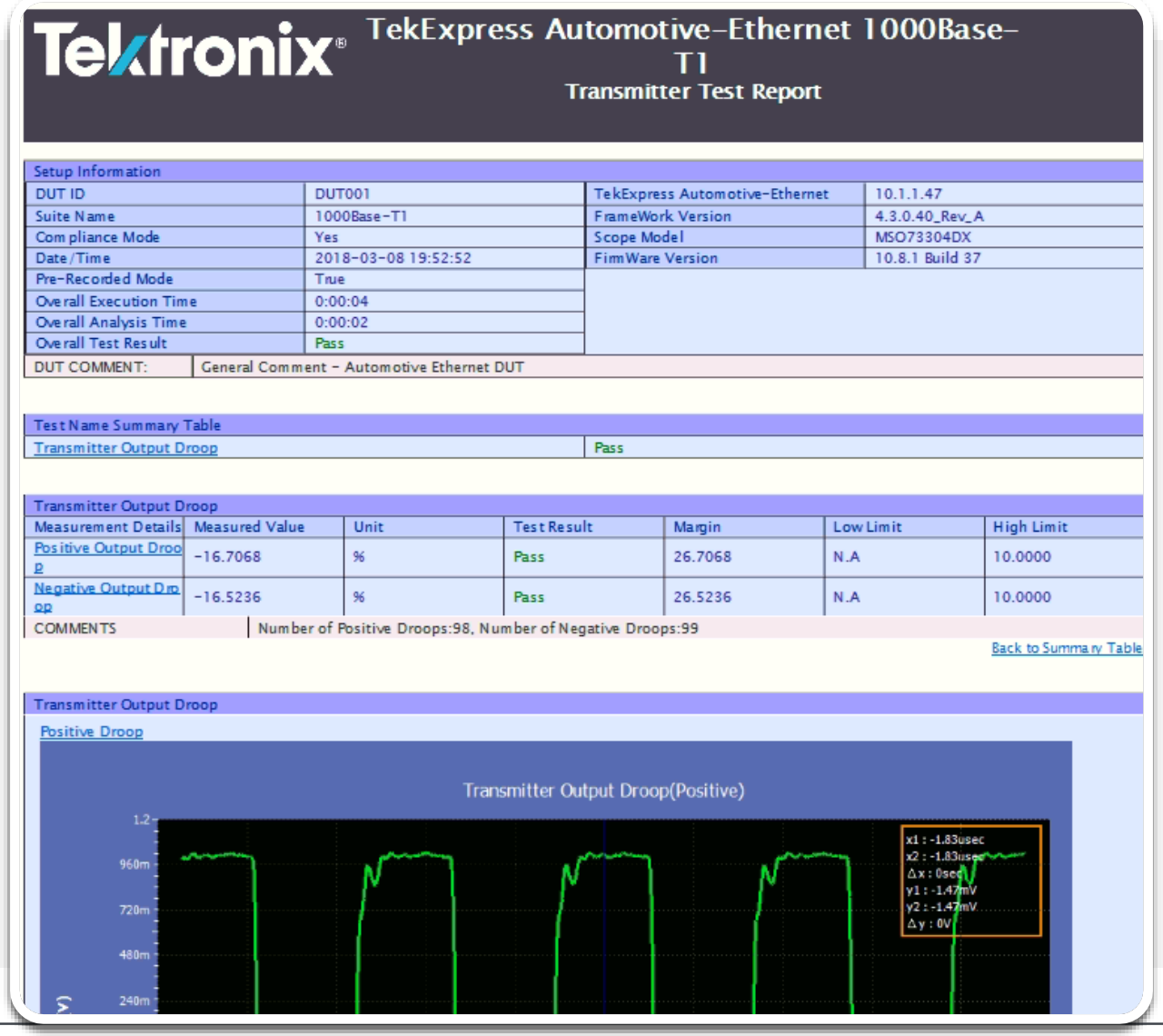
Select multiple tests



Test description with connection diagram

Automated Report Generation

Report with pass/fail, margin and plots



Tektronix®

TekExpress Automotive-Ethernet 1000Base-T1

Transmitter Test Report

Setup Information			
DUT ID	DUT001	TekExpress Automotive-Ethernet	10.1.1.47
Suite Name	1000Base-T1	FrameWork Version	4.3.0.40_Rev_A
Compliance Mode	Yes	Scope Model	MSO73304DX
Date/Time	2018-03-08 19:52:52	FimWare Version	10.8.1 Build 37
Pre-Recorded Mode	True		
Overall Execution Time	0:00:04		
Overall Analysis Time	0:00:02		
Overall Test Result	Pass		
DUT COMMENT:	General Comment - Automotive Ethernet DUT		

Test Name Summary Table	
Transmitter Output Droop	Pass

Transmitter Output Droop

Measurement Details	Measured Value	Unit	Test Result	Margin	Low Limit	High Limit
Positive Output Droop	-16.7068	%	Pass	26.7068	N.A	10.0000
Negative Output Droop	-16.5236	%	Pass	26.5236	N.A	10.0000
COMMENTS	Number of Positive Droops:98, Number of Negative Droops:99					

Back to Summary Table

Transmitter Output Droop

Positive Droop

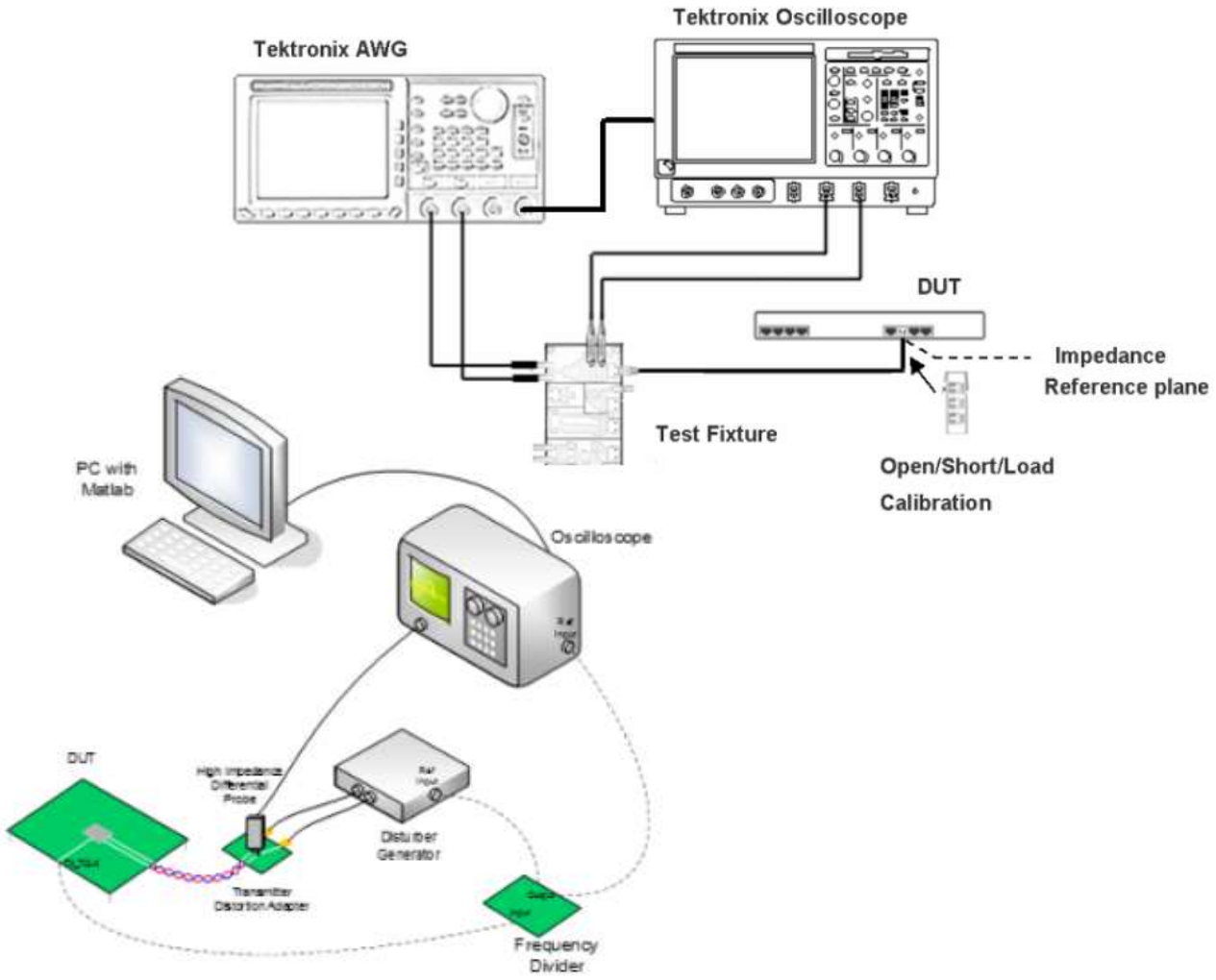
MDI Return Loss, Distortion Test

Return loss measurement

- Test spec references VNA or Scope + AWG as measurement tool
- Return loss measured at the MDI shall be at least 18 dB (*1 to 20 MHz),* and at least 18-10*log10(*f/20*) dB (*20 to 66 MHz*)
- Max & min mask defines limits at 4 specific frequencies
- Tek has patented approach using scope and AWG (*same equipment used for other tests*)

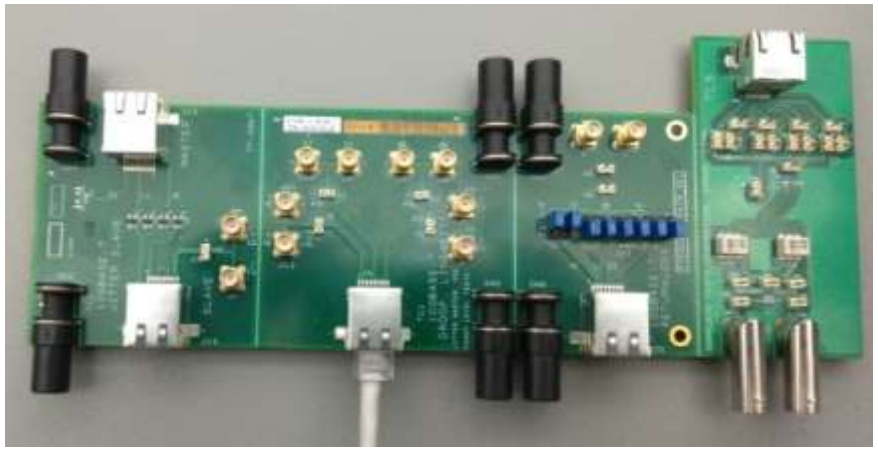
Distortion test

- **Tektronix 100BASE-T1** offers software clock recovery, no need of clock connection or clock divider unit



Signal Access

TDP3500 Probe



TF-XGbT Fixture

Clock Divider

MSO6/MSO5 Scope

Beyond Compliance
System Level troubleshooting

Automotive Ethernet Test Requirement

CAN TO AUTOMOTIVE ETHERNET

OSI	CAN
7. Application	Application
6. Presentation	
5. Session	
4. Transport	
3. Network	
2. Datalink	DLL
1. Physical	PHY

Protocol Test

Protocol Decode, Timing Measurement

Eye Diagram,

OSI	Automotive Ethernet
7. Application	Application
6. Presentation	
5. Session	
4. Transport	TCP/UDP
3. Network	IP
2. Datalink	Network Access
1. Physical	100/1000BASE-T1

Protocol Conformance Test

Protocol Decode, Timing Measurement

Eye Diagram, Compliance

Automotive Ethernet Standard

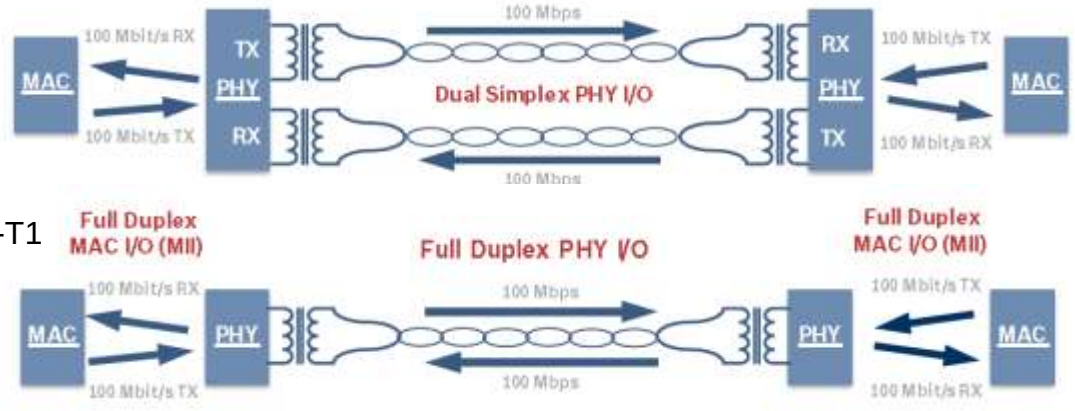
- IEEE Ethernet derivative standard (BroadR-Reach) created by an industry alliance (OABR)
- IEEE has established its own standards 100BASE-T1 (P802.3bw™) and 1000BASE-T1 (802.3bp™)
- Initial deployment focused on 100 Mb/s and 1 Gb/s, early development underway for 10Gbps
- Unshielded single twisted pair cabling designed for automotive use and lower cost
- PAM3 Modulation: Slow rise time, reduces EMI
- Full-Duplex Communication: Reduces cable and increases effective bandwidth

Unshielded single twisted pair cabling designed for use in automotive environments with lower cost

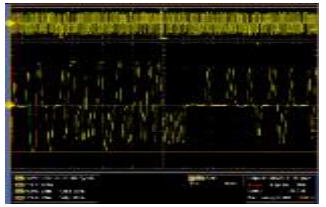
100BASE-T

BRR/100BASE-T1

UTPC



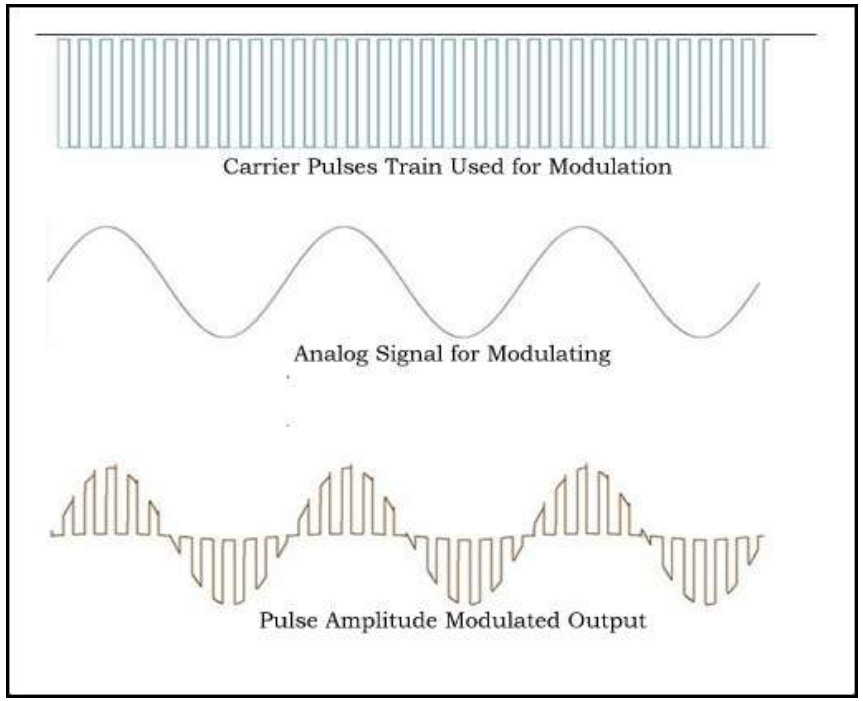
MLT-3



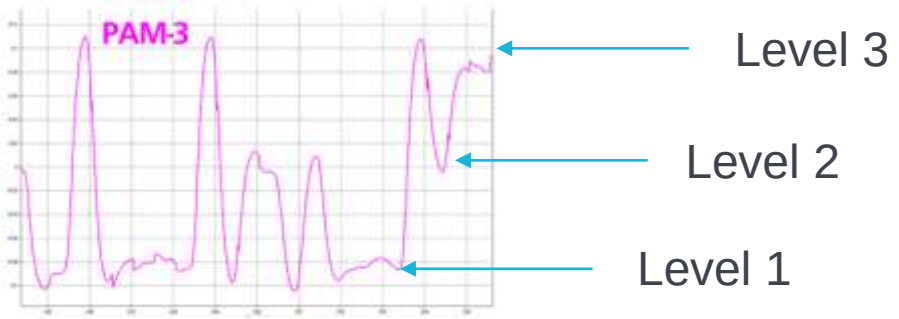
PAM3

What is “PAM” Signaling?

- PAM = Pulse Amplitude Modulation
- Combines train of pulses with a modulating signal → amplitude modulated pulses
- Embeds more information than 01010101 pulses – information encoded into the *amplitude* of the pulse, not just on/off



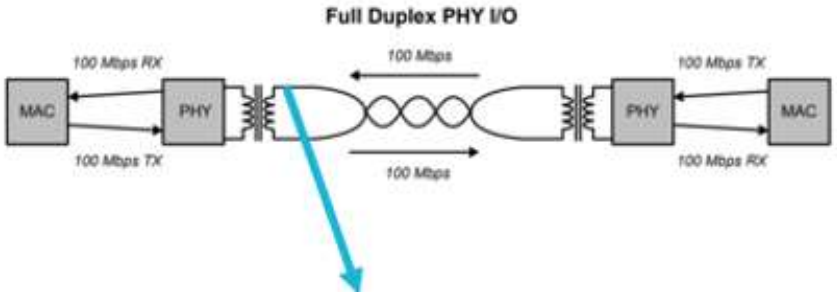
- PAM3 → three levels

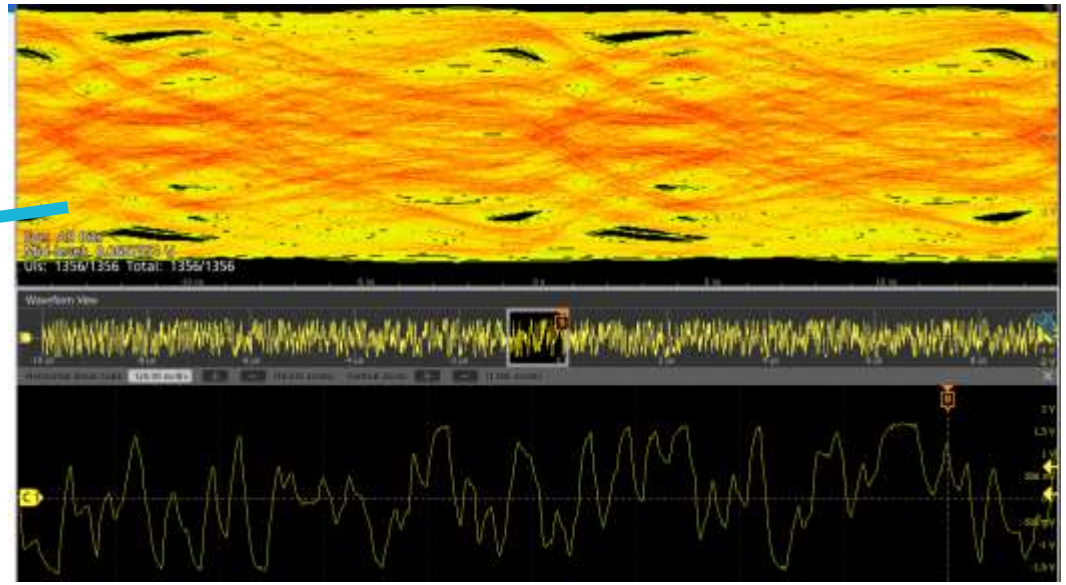


vs.

Challenges at the System Level

- **Reduce Intrusion:** System level testing demands minimal intrusion with the System Under Test.
- **Full Duplex Signals:** signals overlay, meaning that connecting high impedance voltage probes yields no useful information.

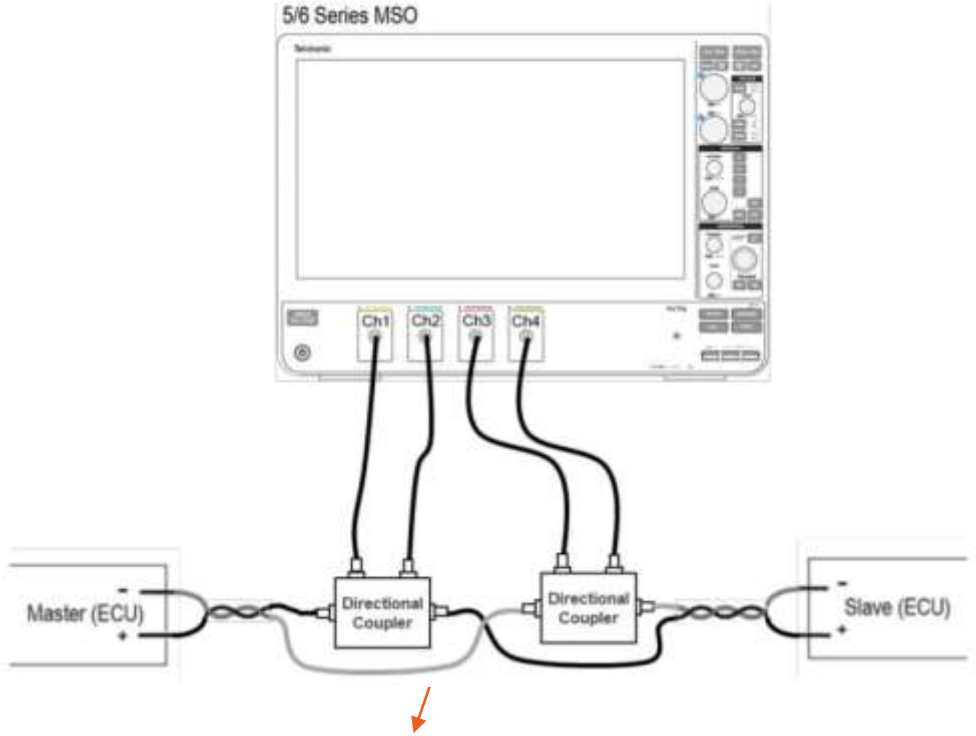




“Huh???”

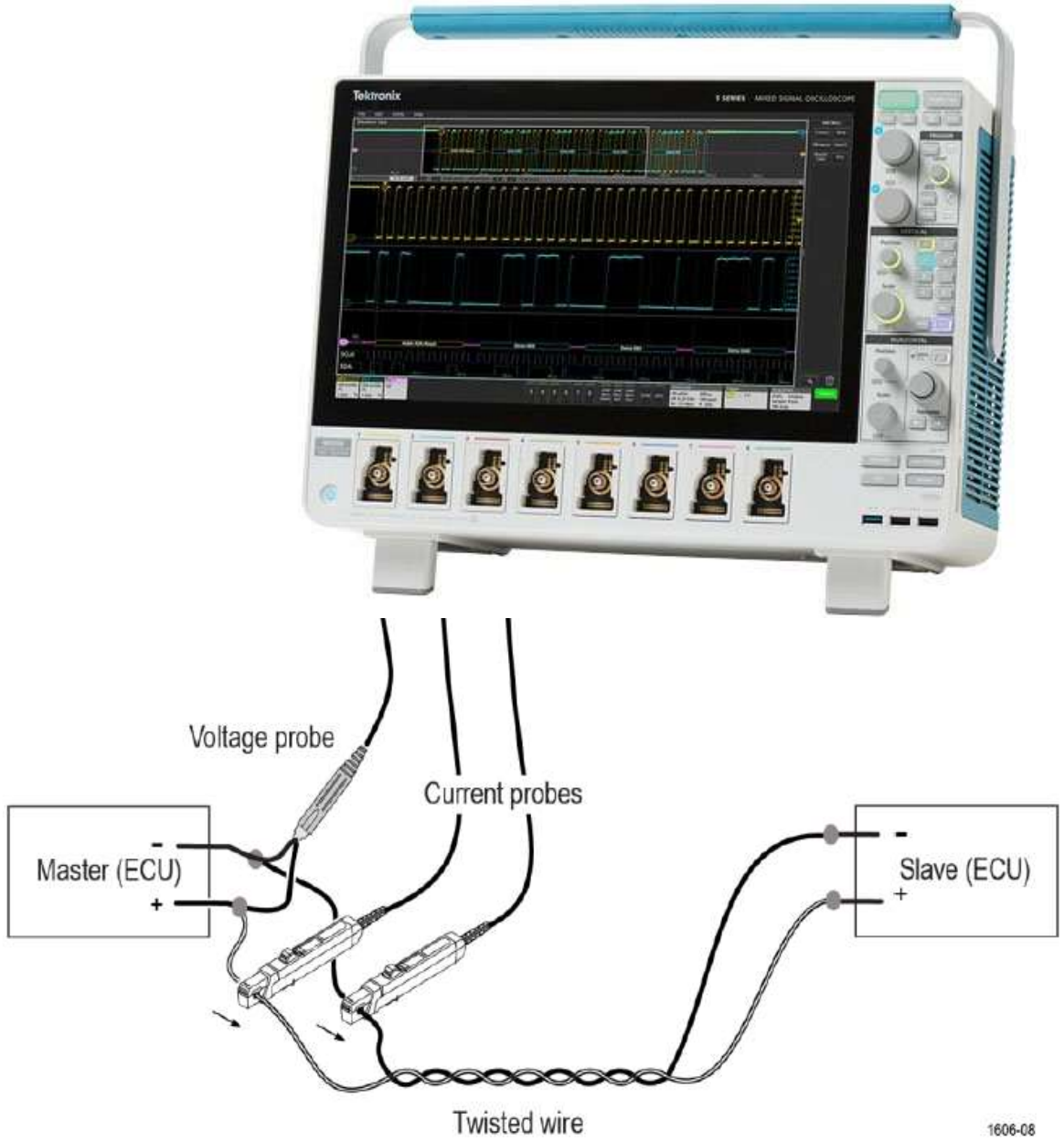
Current solution

- Directional coupler-
  - Cut the cable and disturb the system
  - Directional coupler works on Directivity principle, would not show true Signal for Signal Integrity test
  - Insertion loss, Reflection, Mode conversion loss
  - Propagation delay
  - De-Embedding the signal will degrade Signal to noise ration



Better Signal Separation

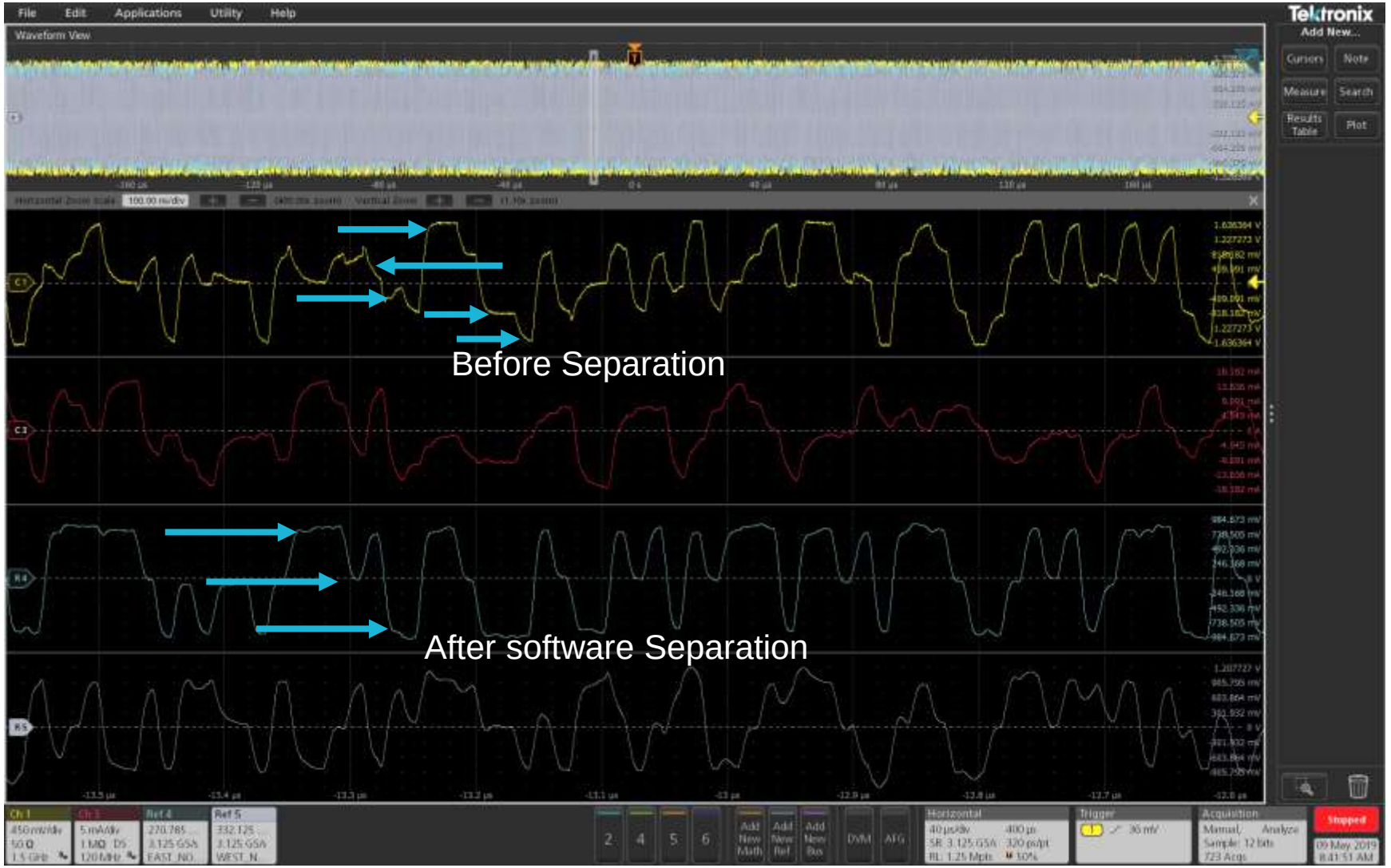
- Tektronix unique (Patent pending) Automotive Ethernet Signal separation solution using Voltage and Current waveform
- Proprietary method to separate Full-dupl signal using Current waveform and Full-Duplex Voltage waveform
- Direct access Probing, no need to break cable, No loading on ECU system
- Provides Master and Slave separated sig



Tektronix Signal Separation Solution

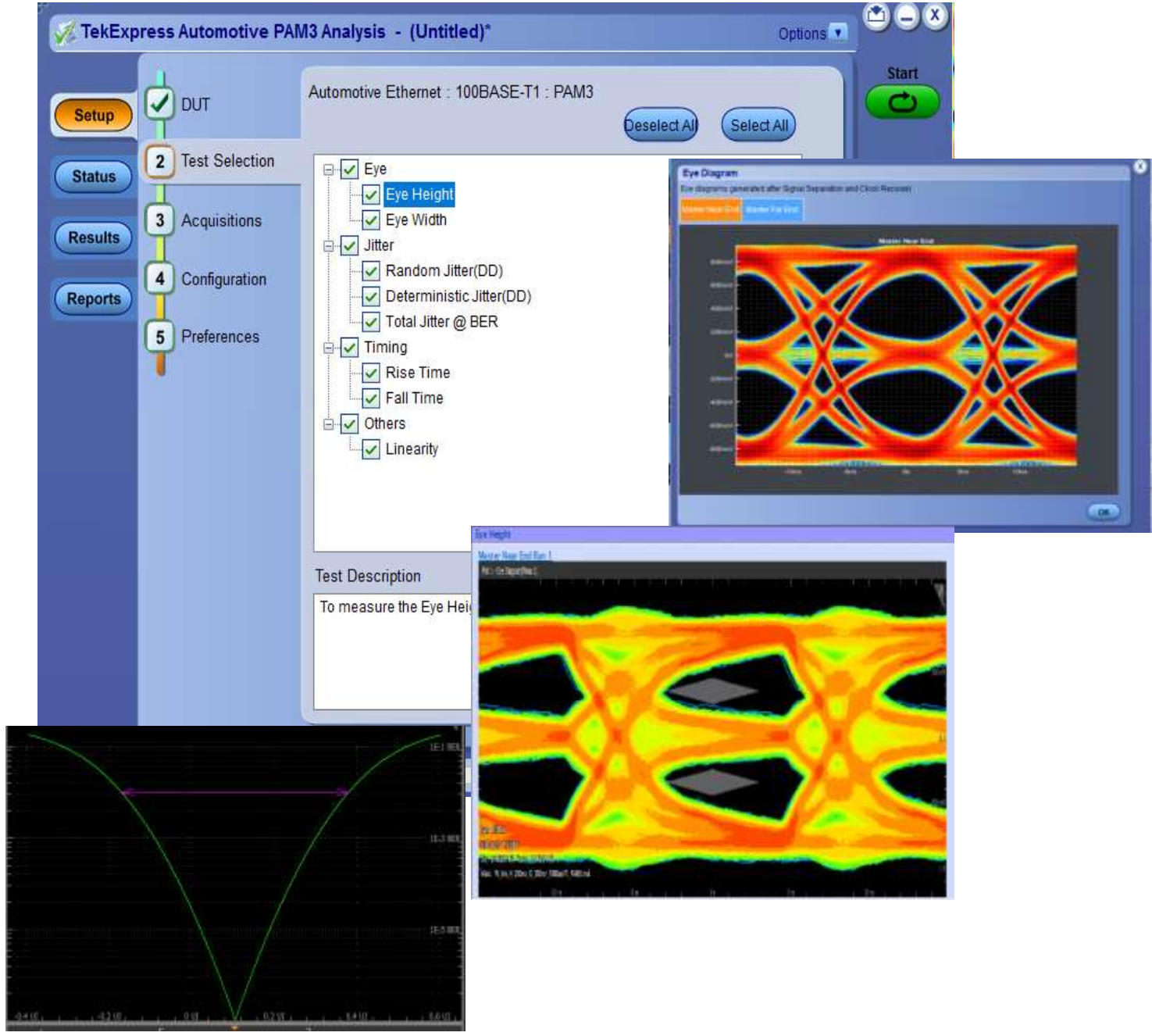
Full-Duplex Signal
Without Signal Separation

PAM3 signal



PAM3 Analysis

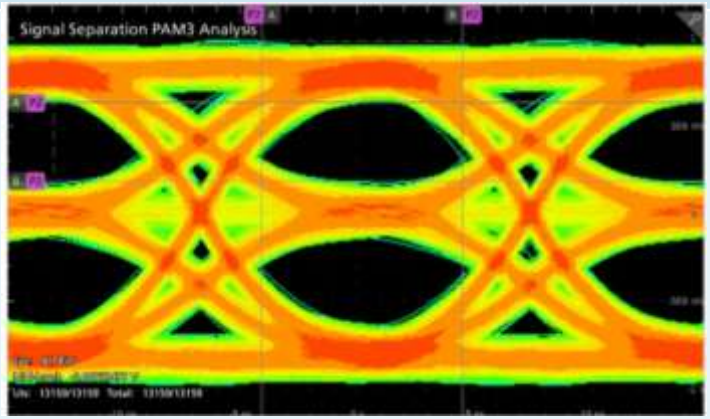
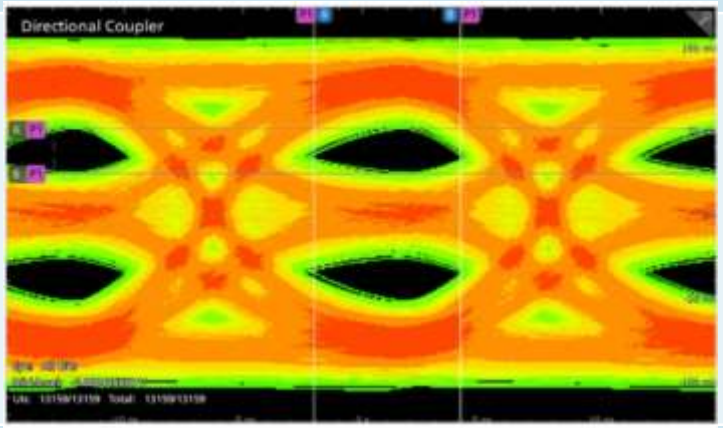
- Software clock recovery
- PAM3 Eye Height and Width
- PAM3 Linearity
- Jitter Separation
- Bathtub curve (BER)
- Eye Mask test



Signal Separation solution

Advantage of Tek solution

See the signal you could never see before

	Tek Solution	Other solution
Test setup	Voltage probe and current probe, Non-Intrusive method	Directional coupler, Automotive Ethernet to SMA convertor
Signal Integrity		
	Vpk-pk: ~2V	Vpk-pk: ~200mv, de-embedding would deteriorate signal to noise ration
Propagation delay	No delay	Varies with different Directional coupler
Advantage	True signal, easy to setup, accurate signal integrity, no need to de-embed	Difficult to use, impacts ECU performance, adds Insertion loss and MDI mode conversion loss

Automotive Ethernet Testing Solutions

Testing an automotive Ethernet often requires an oscilloscope, appropriate probes, a signal source, software and test fixtures. To meet your needs, Tektronix offers a full line of test solutions for Signal Quality and Compliance.

Automotive Ethernet Test	Oscilloscope	Software	Probes	Signal Source	Fixture
Signal Quality Testing (Signal Separation, Protocol Decode, Signal Quality & Debug)	5 Series MSO (Windows only) 6 Series MSO (Windows only)	Option 5/6 -AUTOEN-SS: Signal Separation Option 5/6 -PAM3 (Automotive Ethernet Signal Analysis) Option 5/6 -SRAUTOEN1 (100BASE-T1 Protocol decode) Opt. 5/6 -DJA (Jitter Analysis)	TDP1500 TCP0030A / P6022		ECU Dependent Contact Tektronix for information
Open Alliance TC8 PMA-Tx Compliance Testing	5 Series MSO (Windows only) 6 Series MSO (Windows only)	Opt. 5/6 -CMAUTOEN (1000BASE-T1/100BASE-T1 Compliance) Opt. 5/6 -DJA (Jitter Analysis)	TDP1500 TDP3500	AWG5200 (RL & Distortion) AFG3152C (Distortion only)	TF-XGbT TF-BRR-CFD Contact Tektronix for information
	DPO70000C MSO / DPO70000	Opt. BRR (1000BASE-T1/100BASE-T1 Compliance) Opt. DJA (Jitter Analysis)			

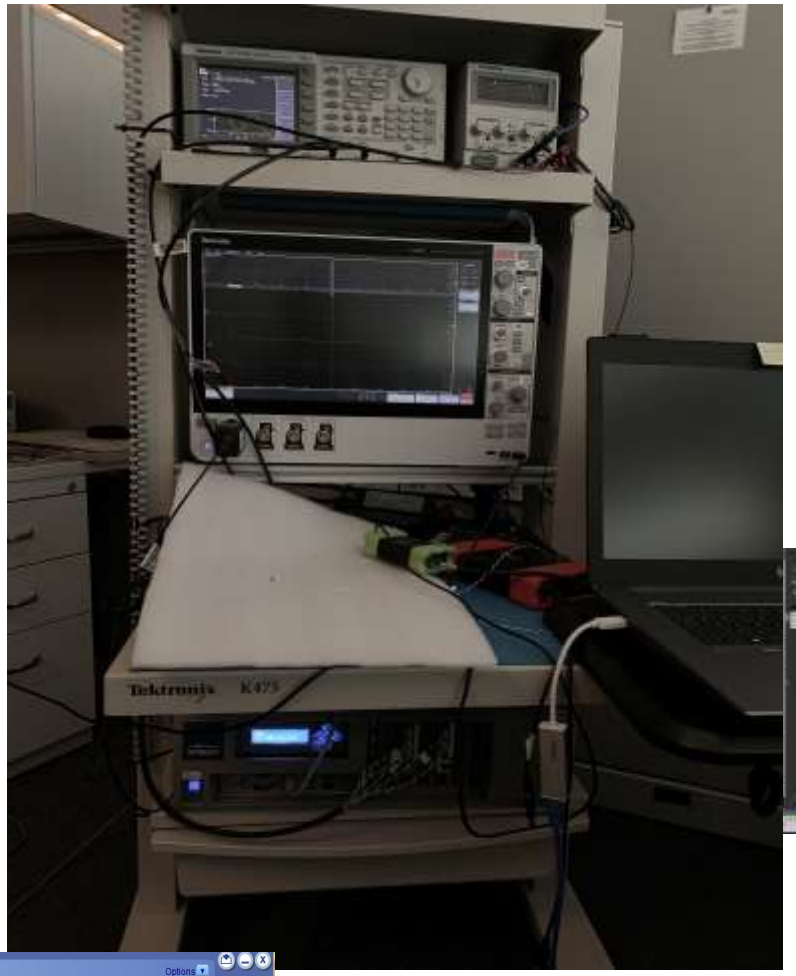
Automotive Ethernet L1-L7 Solution

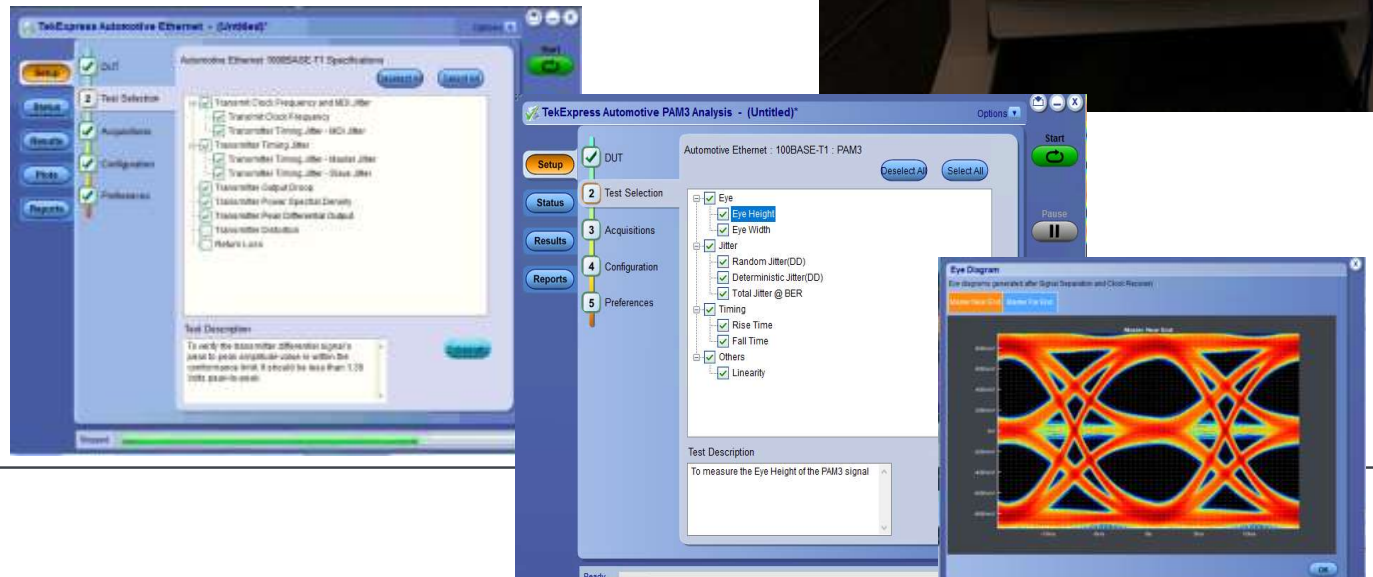
OSI	Automotive Ethernet
7. Application	Application
6. Presentation	
5. Session	
4. Transport	TCP/UDP
3. Network	IP
2. Datalink	Network Access
1. Physical	100/1000BASE-T1

L1-L7 Conformance Test

Protocol Decode, Timing Measurement

Eye Diagram, Compliance





Automotive Ethernet L1-L7

- Layer 7
- Layer 6
- Layer 5
- Layer 4
- Layer 3
- Layer 2
- Layer 1

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INTREPID CONTROL SYSTEMS www.intrepidcs.com

Tektronix

Protocol Layer Conformance

ECU Simulation, Data Loggins

Oscilloscope

AWG/AFG

VNA

Automotive Reference

- Automotive website: www.tek.com/automotive
- Automotive Ethernet: www.tek.com/automotive/automotive-ethernet
- Automotive Power: www.tek.com/power-efficiency/market-your-power-conversion-designs
- EMI/EMC: www.tek.com/application/electromagnetic-interference-emi-and-electromagnetic-compatibility-emc

Signal Separation & PAM3 Demo

THANK YOU