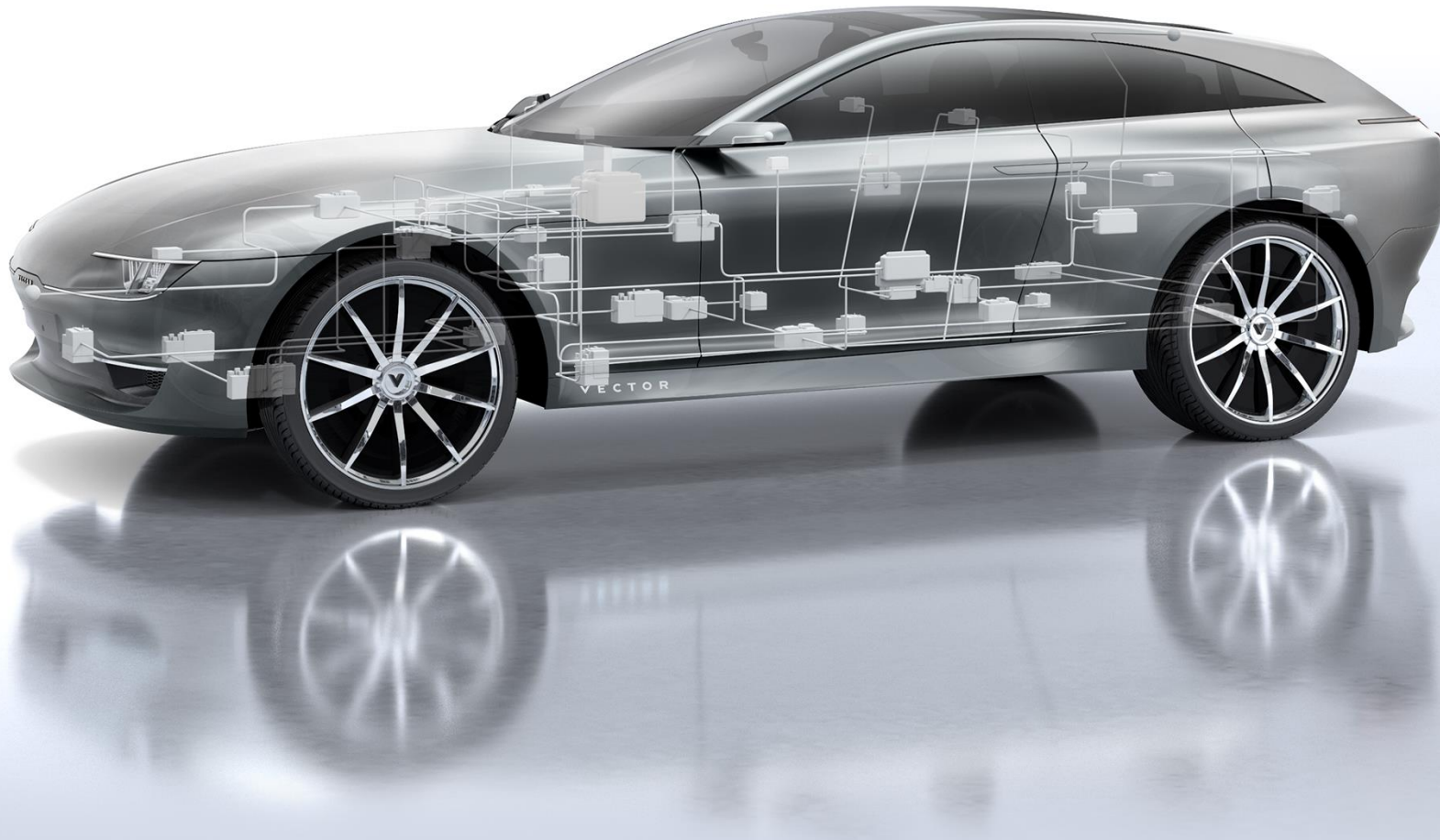


TC8 Conformance Testing of Automotive Ethernet Networks

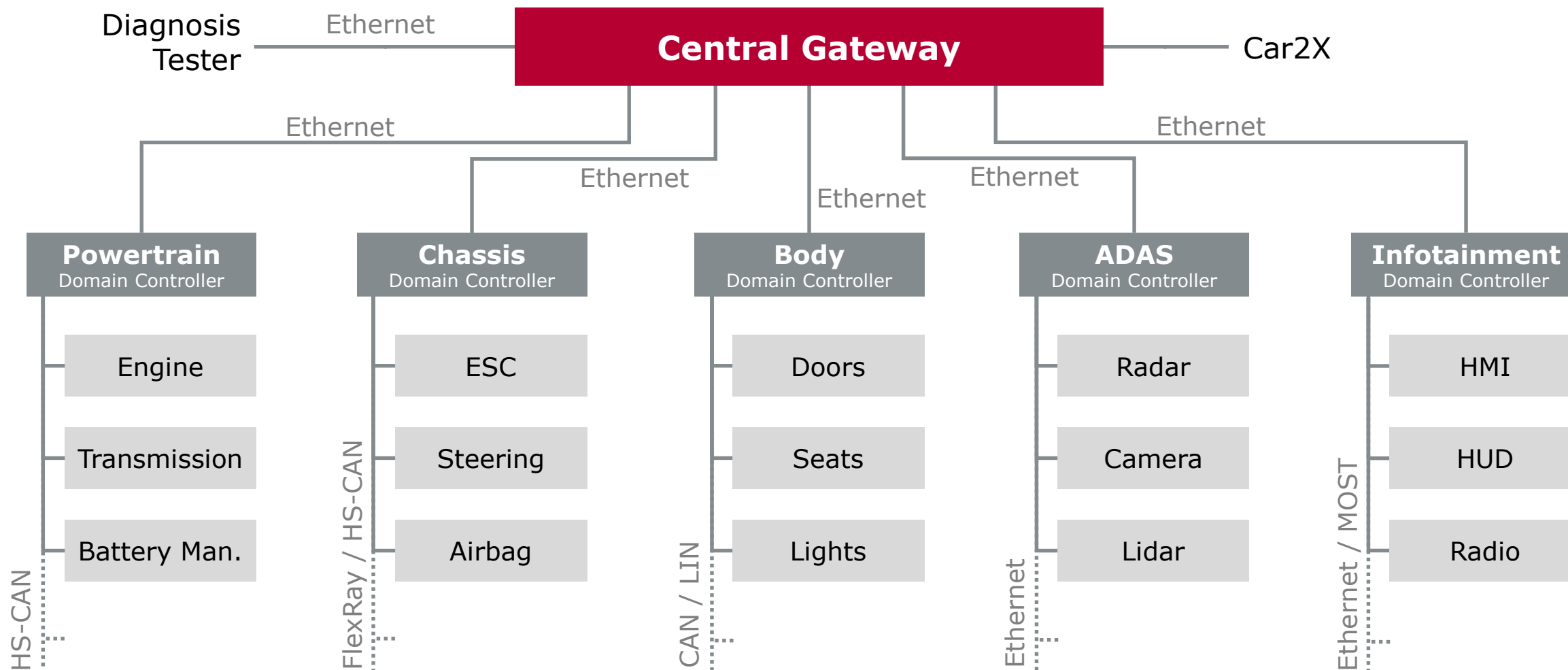
Vector Testing Symposium 7.5.2019 | Heiner Hild

Overview + Motivation

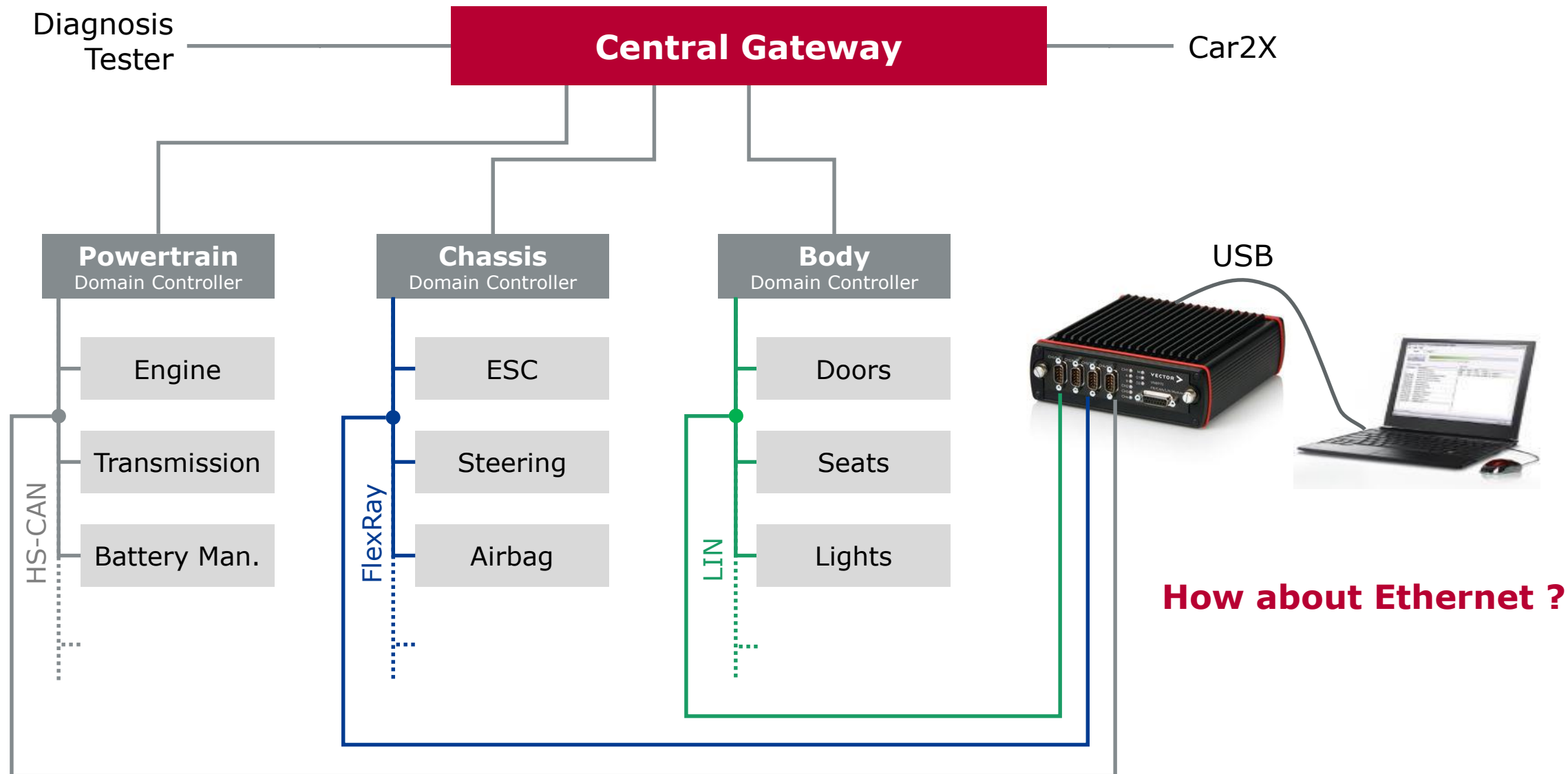
Communication Networks in Domain Centric E/E Architectures



Communication Networks in Domain Centric E/E Architectures



Access to Automotive Bus Systems



Agenda

Overview + Motivation

► **Automotive Ethernet Testing**

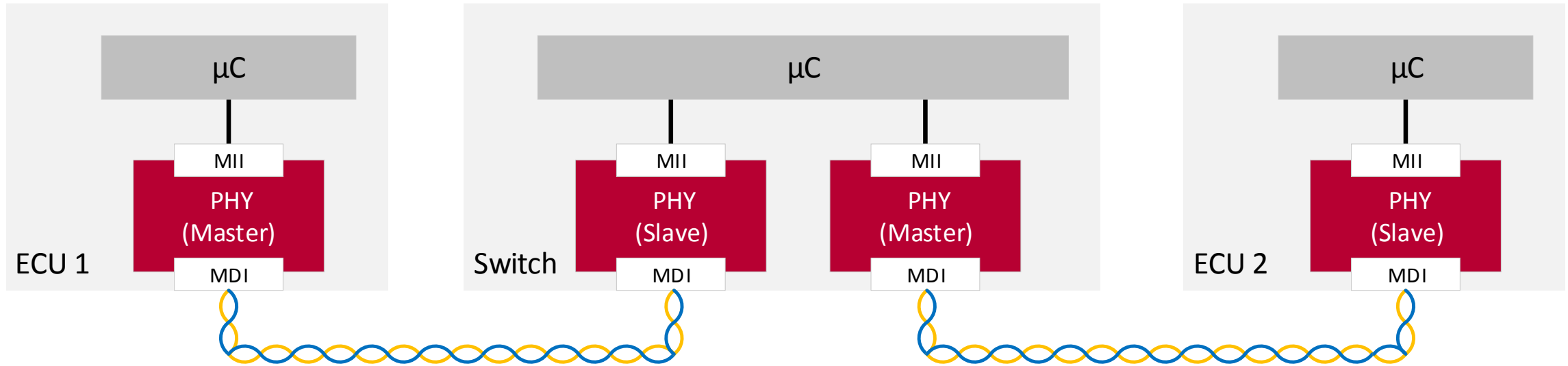
OPEN Alliance SIG

Exemplary Ethernet Test System

Summary

Outlook VT System

Link Partners in Automotive Ethernet Networks

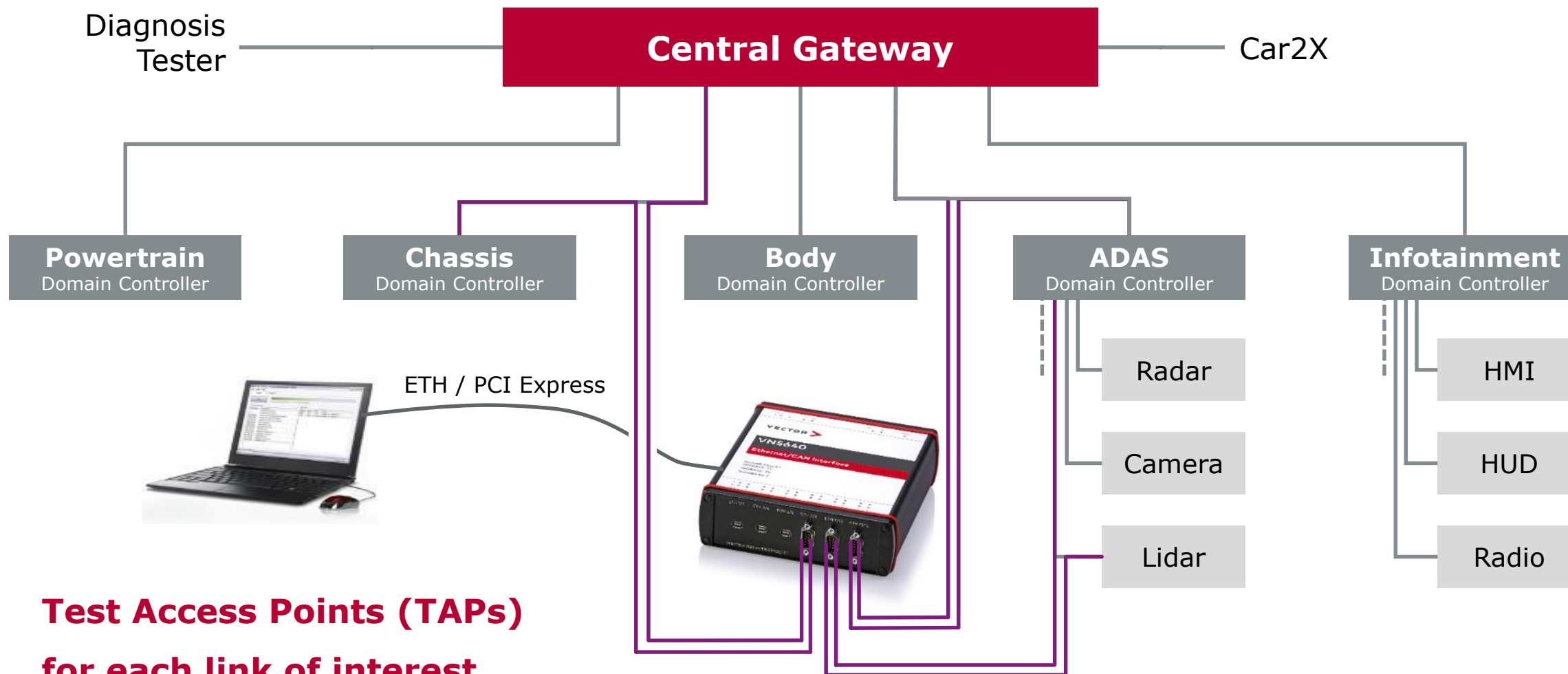


- ▶ All links in Automotive Ethernet networks are Point-To-Point connections → No Bus !
- ▶ Full Duplex transmission
- ▶ More than 2 signal states (e.g. PAM3 at 100BASE-T1)
- ▶ Each link requires one PHY per link partner → multiple PHYs in switches

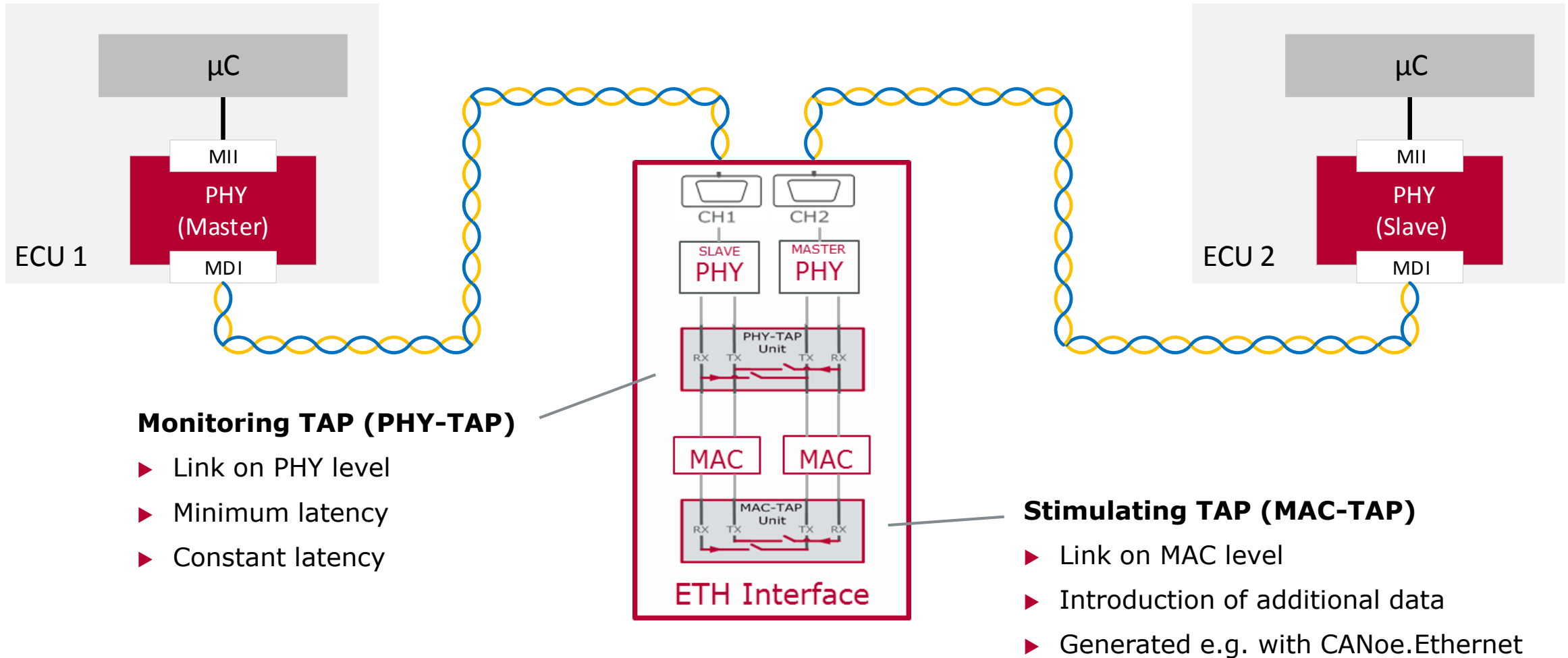
MDI Media Dependent Interface

MII Media Independent Interface

Access to Automotive Ethernet Networks



Ethernet Link TAPping



Agenda

Overview + Motivation

Automotive Ethernet Testing

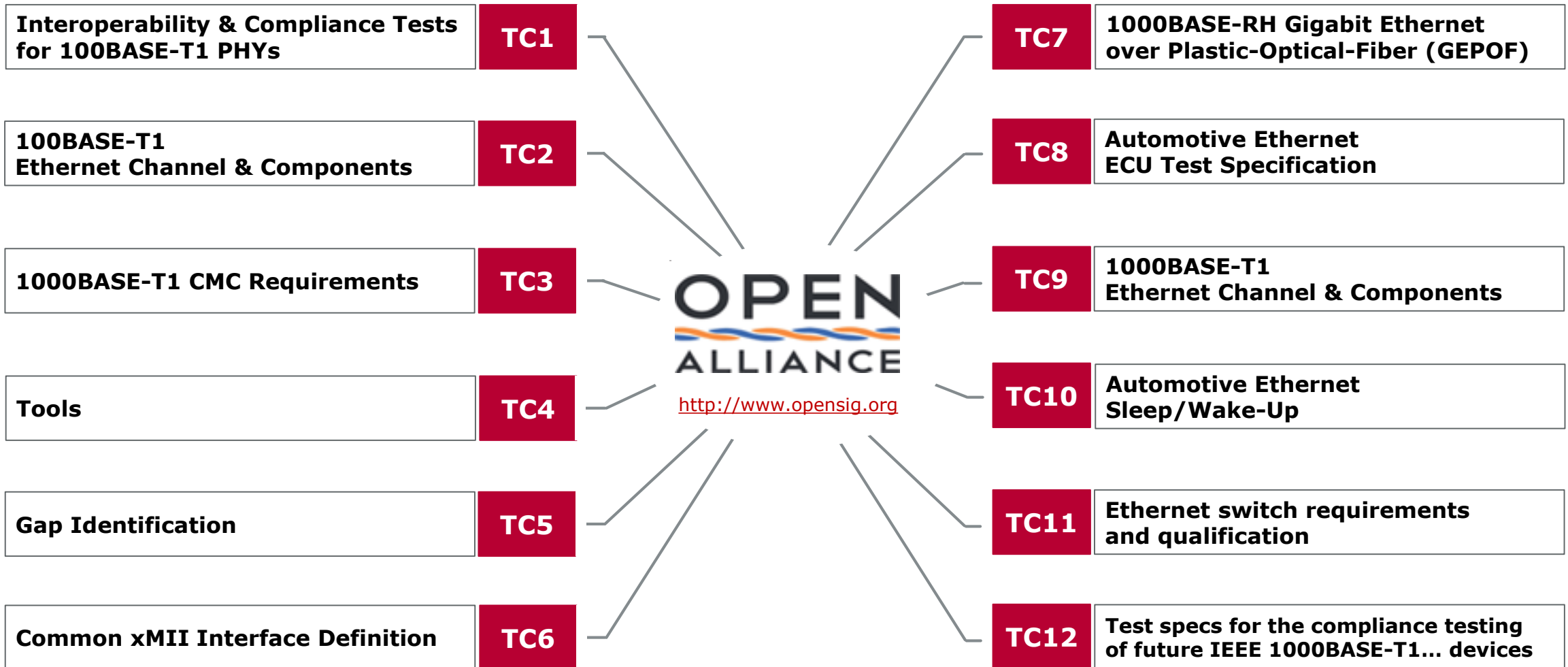
► **OPEN Alliance SIG**

Exemplary Ethernet Test System

Summary

Outlook VT System

Standardisation: OPEN Alliance Special Interest Group (SIG)



Standardisation: OPEN Alliance Special Interest Group (SIG)



<http://www.opensig.org>

TC8

**Automotive Ethernet
ECU Test Specification**

- ▶ **Shares requirements** on Automotive Ethernet ECU testing of Conformance + Interoperability
- ▶ **Defines specifications** applicable to all ECUs in an Automotive Ethernet network based on these shared requirements.
- ▶ **Defines test process** and supports the establishment of test houses that can perform the ECU tests
- ▶ **Establishes regular audits** of the test specification and the partner requirements to increase the communication quality of the Ethernet ECUs and network in an automotive system

Target: Testing on ECU level as early as possible in the development phase

Automotive ISO/OSI Layer Model – Application Areas and TC8 Test Scopes

TC8 ECU Test

Test Scope

ISO/OSI Layer

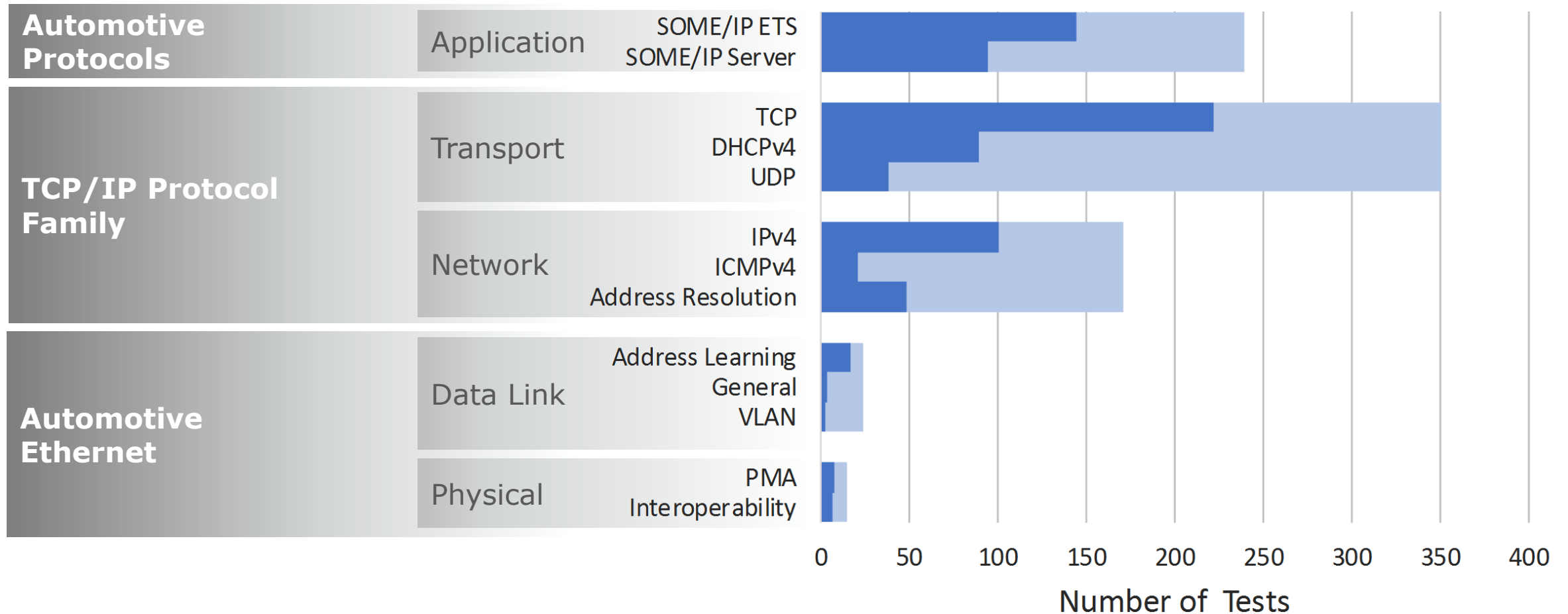
Command / Control
communicationDiagnostics and
Flash UpdateMeasurement and
CalibrationAudio/Video
Time Sync

Automotive Protocols	Application	7	SOME/IP	DoIP	XCP	AVB / TSN
		6				
		5				
TCP/IP Protocol Family	Transport	4	TCP/UDP			
	Network	3	IPv4/IPv6			
Automotive Ethernet	Data Link	2	IEEE Ethernet MAC + VLAN			
	Physical	1	Ethernet PHY (IEEE 100BASE-T1, IEEE100BASE-Tx, IEEE1000BASE-T)			

Test Groups in the TC8 Tests

TC8 ECU Test
Test Scopes

ISO/OSI Layer



Agenda

Overview + Motivation

Automotive Ethernet Testing

OPEN Alliance SIG

► **Exemplary Ethernet Test System**

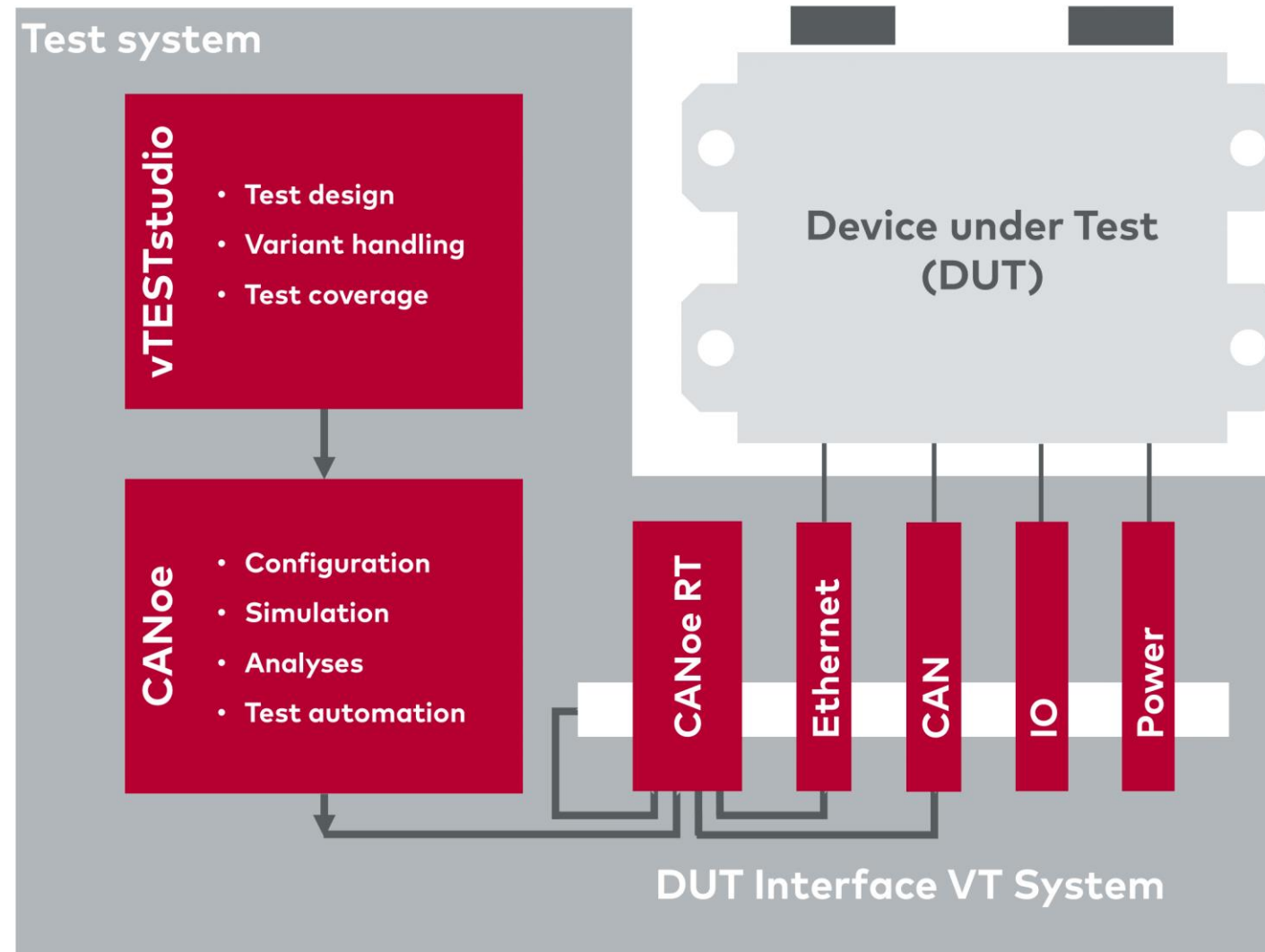
Summary

Outlook VT System

Test System CANoe + vTESTstudio + VT System

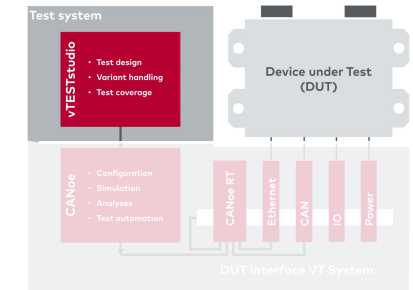
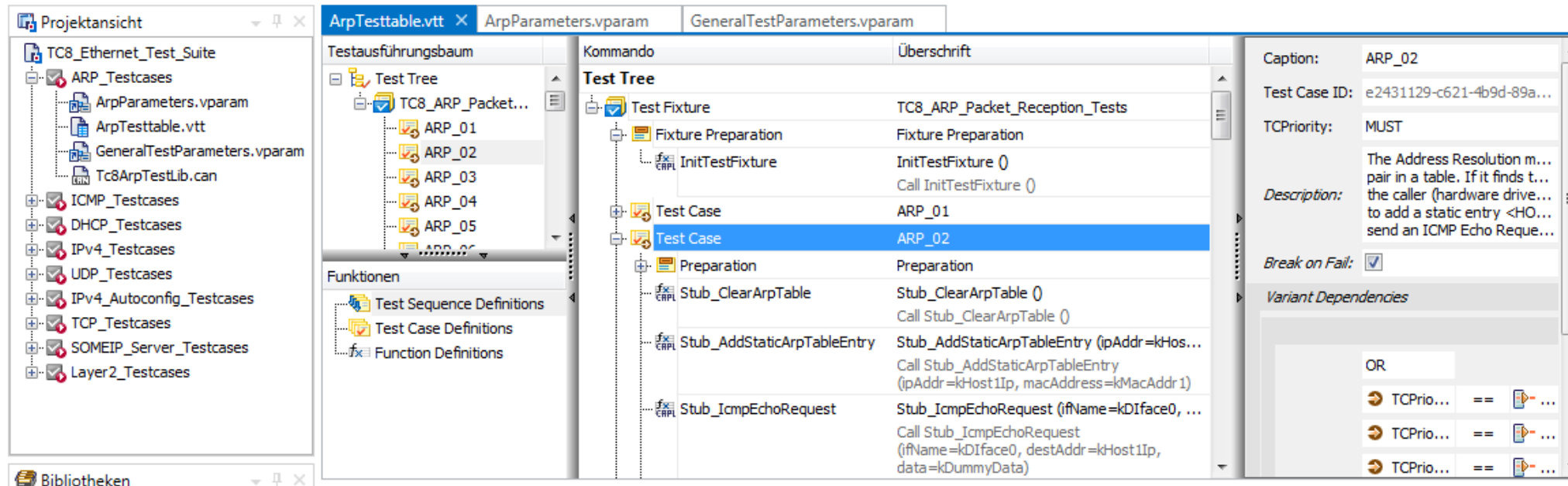
Target

- One Test System for all ISO/OSI layers



TC8 Test Implementation

- ▶ Implementation in vTESTstudio
- ▶ Test configuration
 - ▶ One global parameter file (general settings for the DUT, e.g. IP address)
 - ▶ One specific parameter file for each Test Group

Kommando	Überschrift
Test Tree	
Test Fixture	TC8_ARP_Packet_Reception_Tests
Fixture Preparation	Fixture Preparation
InitTestFixture	InitTestFixture () Call InitTestFixture ()
Test Case	ARP_01
Test Case	ARP_02
Preparation	Preparation
Stub_ClearArpTable	Stub_ClearArpTable () Call Stub_ClearArpTable ()
Stub_AddStaticArpTableEntry	Stub_AddStaticArpTableEntry (ipAddr=kHos... Call Stub_AddStaticArpTableEntry (ipAddr=kHost1Ip, macAddress=kMacAddr1)
Stub_IcmpEchoRequest	Stub_IcmpEchoRequest (ifName=kDiface0, ... Call Stub_IcmpEchoRequest (ifName=kDiface0, destAddr=kHost1Ip, data=kDummyData)

Caption: ARP_02

Test Case ID: e2431129-c621-4b9d-89a...

TCPriority: MUST

Description: The Address Resolution m... pair in a table. If it finds t... the caller (hardware drive... to add a static entry <HO... send an ICMP Echo Reque...

Break on Fail: ☒

Variant Dependencies

OR

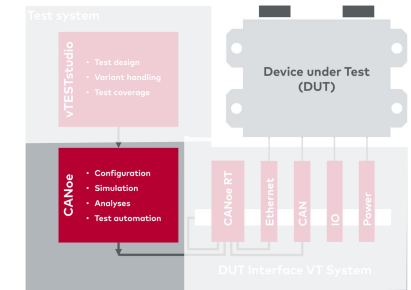
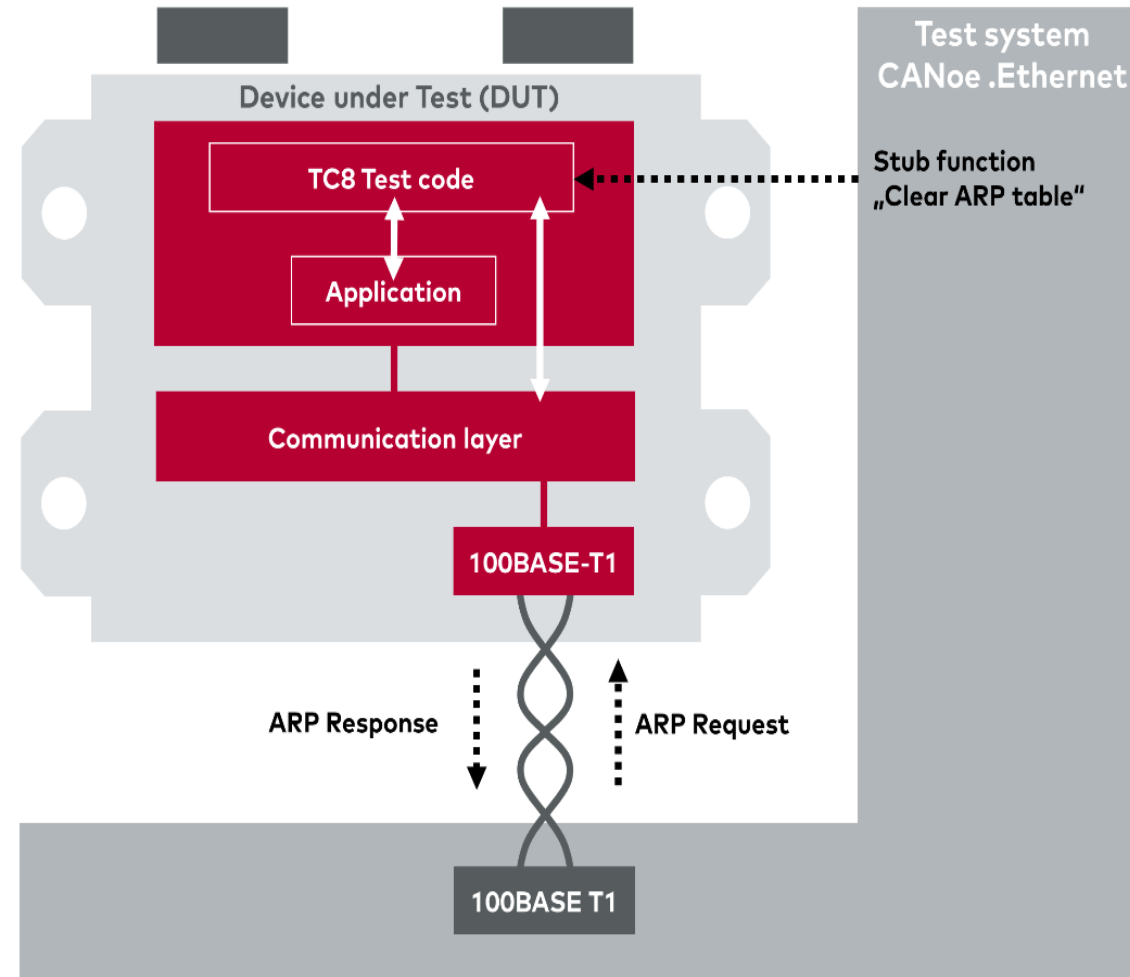
TCPrio... == ...

TCPrio... == ...

TCPrio... == ...

TC8 Test Execution

- ▶ Specific Test Code on ECU
- ▶ Specific Stub Functions to prepare ECU for test (typically CAPL)
- ▶ E.g. ARP-Test: Stub Function „Clear ARP Table“ ensures cleaned MAC address table **before** test execution
- ▶ Simulated Reference DUT („Golden Sample“) in CANoe to run TC8 Tests fail free



VT6306 Ethernet Interface

- ▶ 6 Automotive Ethernet channels on separate piggy board
- ▶ 2x 100BASE-TX/1000BASE-T channels on main board
- ▶ High precision time stamps for Ethernet frames
- ▶ Synchronization with multiple bus interfaces
- ▶ Hardware sync (1 μ s accuracy)
- ▶ Ethernet Monitoring between two nodes
- ▶ Media conversion between 100BASE-TX/1000BASE-T and Automotive Ethernet channels
- ▶ Flexible, hardware based monitor filter
- ▶ Multiple, configurable Test Access Points (TAPs)
 - ▶ Monitoring TAP: test mode with constant and very low latency with direct PHY connection
 - ▶ Stimulation TAP: channel connection an MAC level. This allows transmission of additional packets
- ▶ Configurable layer2-switch operation mode
- ▶ Further Ethernet Interfaces available



Automotive Ethernet Interfaces



	VN5610A	VN5640	VT6306 + piggy	VN5620	VN5430
User Ports					
100/1000BASE-T1	2x 100BASE-T1	12x	6x	4x	6x
10BASE-T/100BASE-Tx/ 1000BASE-T	2x	4x	2x	--	--
CAN / CAN FD	2x	2x	--	2x	--
I/O Channels	1x digital	1x analog 5x digital	Arbitrary number from VT System	1x digital	--
Fault Injection on physical layer	no	no	yes	no	no
Host Connection	USB2.0	USB3.0	PCI Express	USB3.1 Ethernet	Ethernet
Powering	USB / External	External	via VT System	USB / External	External

TC8 Testing - Summary

- ▶ Automotive Ethernet
 - ▶ Occurrence in modern EE architectures
 - ▶ Difference to classical Bus Protocols
 - ▶ Link Access with TAPs

- ▶ OPEN Alliance SIG
 - ▶ Structure
 - ▶ TC8 – Tests with Test Scopes for all ISO/OSI layers

- ▶ Exemplary TC8 Test System
 - ▶ Test implementation in vTESTstudio: Parameter files to adapt to specific ECU
 - ▶ Test execution with CANoe: Stub Functions acting on specific test code + Golden Sample
 - ▶ DUT interfacing with VT System / various ETH interfaces

Agenda

Overview + Motivation

Automotive Ethernet Testing

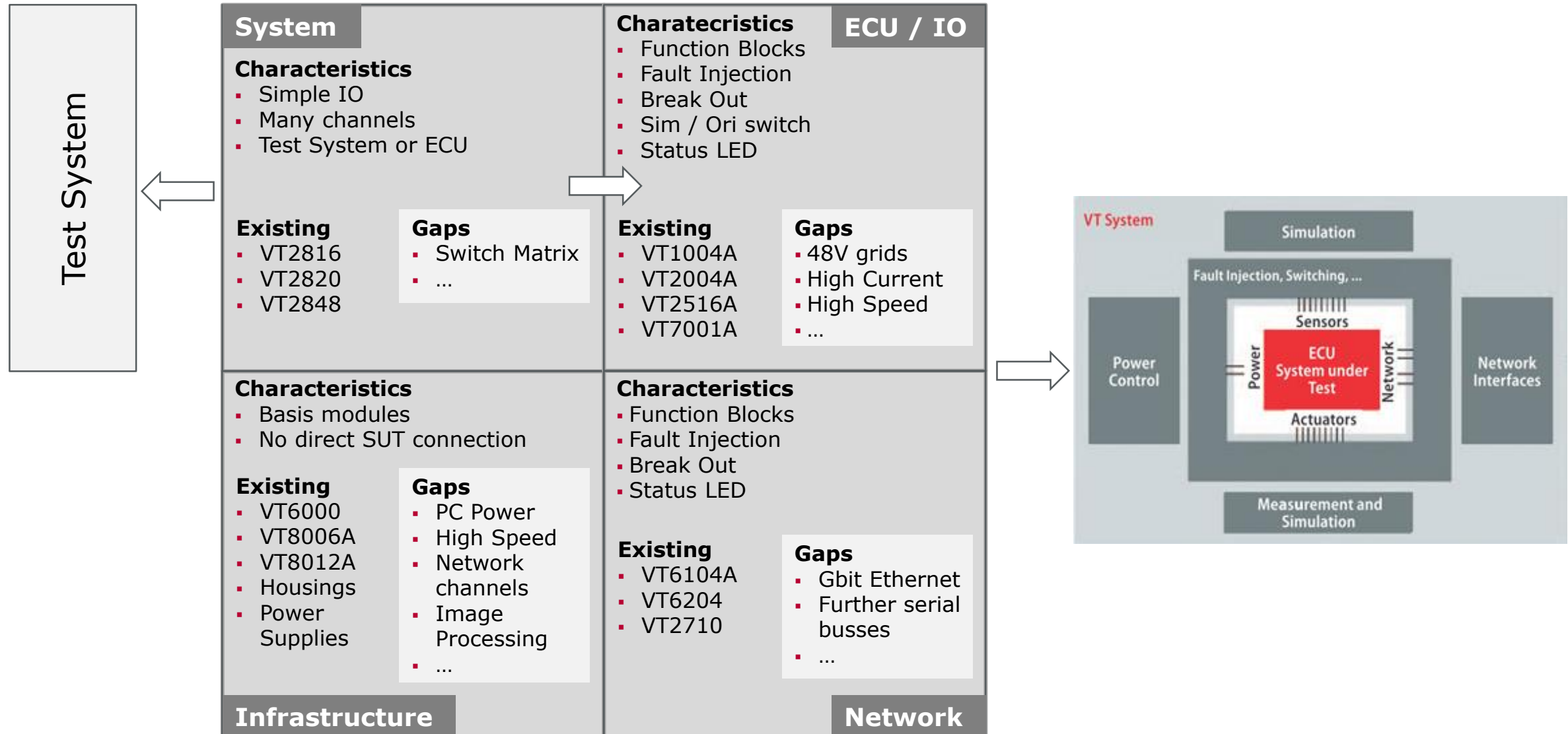
OPEN Alliance SIG

Exemplary Ethernet Test System

Summary

► **Outlook VT System**

VT System Concept



VT2832 - Switch Matrix Module

Motivation

- ▶ Switching of higher currents
- ▶ PWM switching / bouncing contact simulation
- ▶ Many switching cycles (endurance tests)

Main Features

- ▶ Size of switch matrix: 8 columns x 4 rows
- ▶ Current carrying capability per switched path: max. 16A
- ▶ Coupling of channels for higher currents possible
- ▶ Switched voltage up to 60V
- ▶ Modular Design → aggregation to bigger switch matrices possible
- ▶ Solid State Relay (SSR) technology → wear-free switching for endurance tests
- ▶ Fast switching with min. 10 kHz possible e.g. for bouncing contact simulation



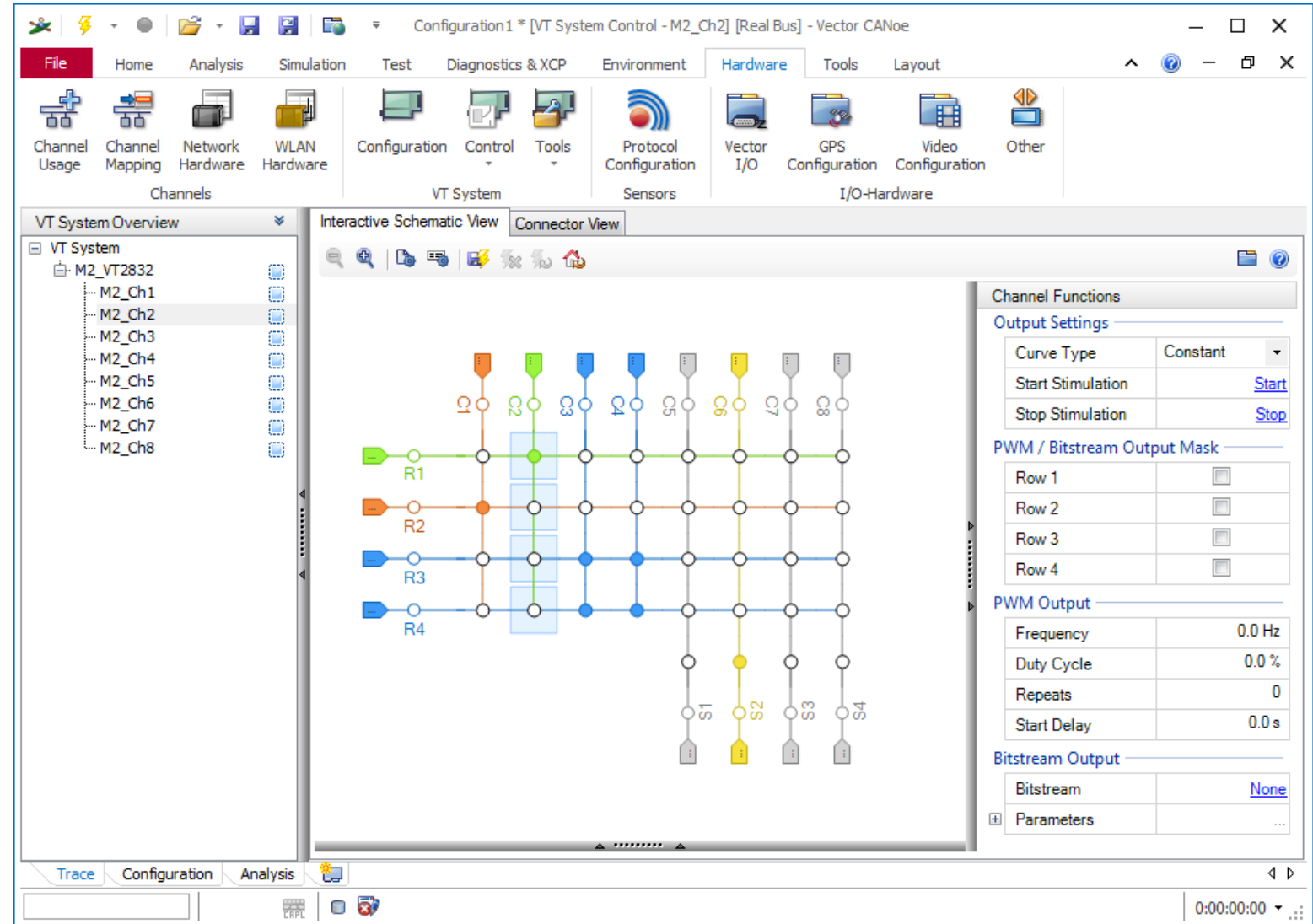
VT2832 - Switch Matrix Module

Use Cases

- ▶ Current switching + measurement
- ▶ PWM switching / bouncing contact simulation
- ▶ Endurance Tests

Configuration

- ▶ Each switched path is given a unique colour
- ▶ Connected paths are given the same color
- ▶ Each column can be switched independently with PWM or bitstream
- ▶ PWM and bitstream configuration is identical to other VT System modules



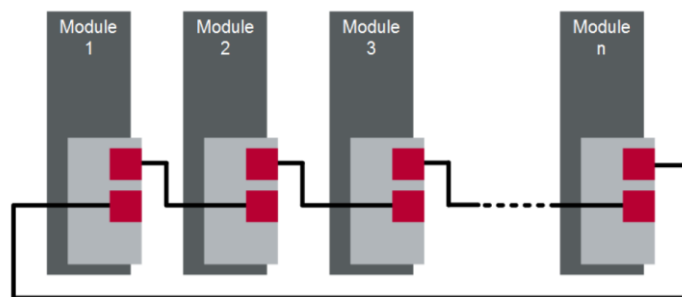
Inter Board Communication (IBC) between User FPGA Modules

Use Cases

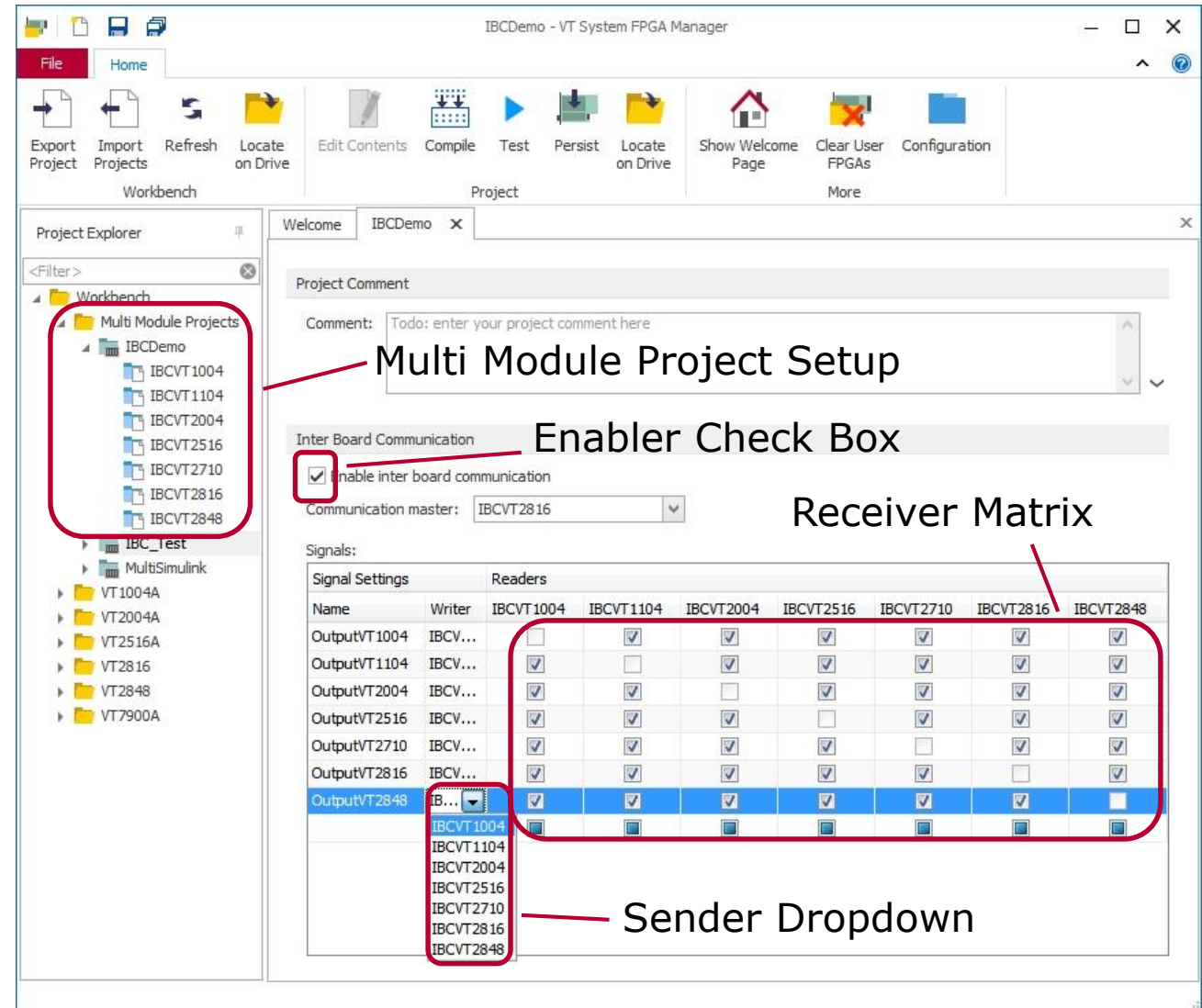
- ▶ Highly synchronized output of analog and/or digital signals
- ▶ Fast data exchange between User FPGA modules

Realisation

- ▶ Ring architecture between User FPGA processor boards



- ▶ Simultaneous flashing of multiple VT System User FPGA module is now possible in VT System FPGA Manager



Multi Module Project Setup

Project Comment: Todo: enter your project comment here

Inter Board Communication

☒ Enable inter board communication

Communication master: IBCVT2816

Receiver Matrix

Signal Settings	Readers	IBCVT1004	IBCVT1104	IBCVT2004	IBCVT2516	IBCVT2710	IBCVT2816	IBCVT2848
OutputVT1004	IBCV...	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
OutputVT1104	IBCV...	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
OutputVT2004	IBCV...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
OutputVT2516	IBCV...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
OutputVT2710	IBCV...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
OutputVT2816	IBCV...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
OutputVT2848	IB...	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

Sender Dropdown

- IBCVT1004
- IBCVT1104
- IBCVT2004
- IBCVT2516
- IBCVT2710
- IBCVT2816
- IBCVT2848

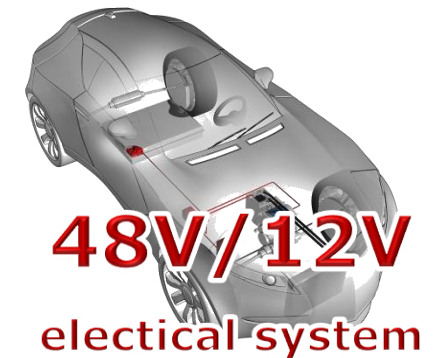
48V – Vehicle Power Support

Motivation

- ▶ Hybrid 48V / 12V electrical systems are becoming more important
- ▶ Testing of 48V EE systems requires measurement / stimulation > 54V

Main Features

- ▶ 60V capability
- ▶ Solid State Relay (SRR) based solution
- ▶ Solutions for
 - ▶ ECU outputs: VT1104 (60V-Variant of VT1004A)
 - ▶ ECU Power Supply: VT7101 (60V-Variant of VT7001A)
 - ▶ Configuration concept is maintained
- ▶ Internal Power Supply of VT7101 up to 60V / 0.5A



	VT1104	VT7101
DC measurement	●	●
DC output		●
Arbitrary curves		●
Fault injection / switching	●	●

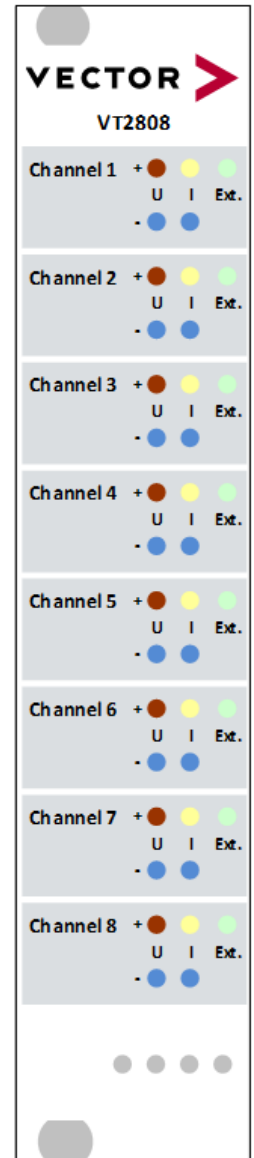
VT2808 Current Measurement Module

Motivation

- ▶ Current measurement on ECU I/Os is often required as a separate task
- ▶ Limitations of available VT System options for current measurement
 - ▶ VT2816
 - ▶ 8 channels up to 5A
 - ▶ cost per channel = ok / range + accuracy sometimes too small
 - ▶ VT7001A
 - ▶ 2 channels up to 100A
 - ▶ range = ok / cost per channel relatively high due to further functions

Main Features

- ▶ 8 current measurement channels
- ▶ Measurement range: 1 mA ... 16A onboard
- ▶ Switch to external shunts (off-board) for increased measurement range
- ▶ Voltage measurement up to 60V against external potential
- ▶ Detection + indication of current flow direction
- ▶ Determination of conducted power per channel



VT60xx Next Gen RT Module (Concept)

Motivation

- ▶ Number of bus channels with VT6051A is limited to 16
- ▶ Some applications e.g. realtime simulations require higher computing power
- ▶ More Ethernet connectors e.g. for LXI measurement devices or PC coupling
- ▶ Connector system for host uplink PCIe (x1) over cable is discontinued

Main Requirements

- ▶ Processor minimum intel Core i7 Gen.7 / QuadCore
- ▶ Minimum 32 bus channels can be operated via VT System Network Interface
- ▶ Minimum 2 additional Gbit/s general purpose Ethernet ports (min. 4x overall)
- ▶ Minimum 2 USB3.0 ports
- ▶ Space consumption: 2 slots in VT System Housing

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Thanks for your attendance

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