TECHNICAL INNOVATIONS

DIAGNOSTICS

OBD evolves for ICE and zero-emission propulsion systems

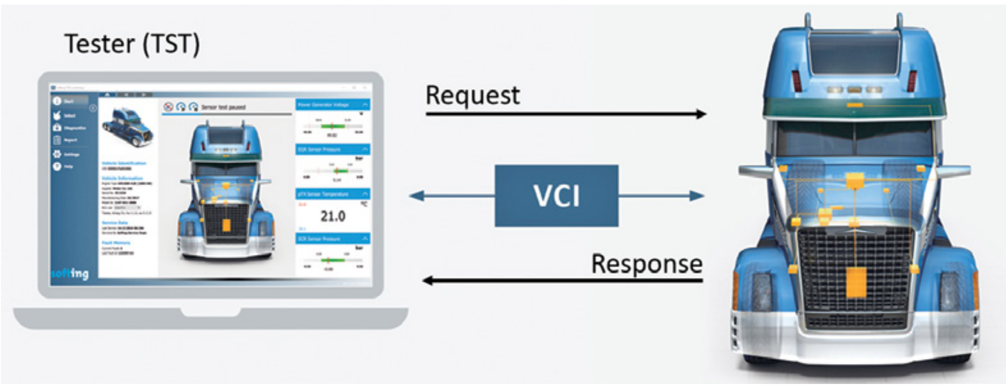

Figure 1: Setup of a traditional diagnostic communication system in the workshop.

On-board diagnostics (OBD) systems support the protection of the environment against harmful pollutants such as carbon monoxide (CO), nitrogen oxide (NOx), hydrocarbons (HC) and particulate matters (PM) emitted by combustion engines. OBD regulations require passenger cars and light-, medium- and heavy-duty trucks to support a minimum set of diagnostic information to external (off-board) "generic" test equipment.

For the purpose of communication, both the test equipment and the vehicle must support the same communication protocol stack. The communication protocol **SAE** J1979, also known as **ISO** 15031, that has been in use for decades will be replaced by SAE J1979-2 for vehicles with combustion engines and by SAE J1979-3 for zero-emission-vehicle (ZEV) propulsion systems.

SAE J1979-2 was published in April 2021 and is allowed by the **California Air Resources Board** (CARB) starting with the 2023 model year and is mandatory by 2027 MY. SAE J1979-3 was published in December 2022. CCR §1962.5 states that SAE J1979-3 is mandated for all ZEVs by 2027. Both protocols are based on ISO 14229-1 UDS.

OSI Layer	Name	Content
7	Application Layer	Requests, pos. / neg. Resonses, SIDs, NRCs
6	Presentation Layer	DIDs, DTCs, FTBs, FMI, SPN
5	Session Layer	
4 3	Transport Layer Network Layer	DoCAN, DoIP
2 1	Data Link Layer Physical Layer	UTP, CAN, 100BASE-TX, Ethernet

SID	Service Identifier
NRC	Negative Response Code
DID	Data Identifier
DTC	Diagnostic Trouble Code
FTB	Failure Type Byte
FMI	Failure Mode Identifier
SPN	Suspect Parameter Number
DoCAN / DoIP	Diagnostics on CAN / Interbnet Protocol
UTP	Unshielded Twisted Pair (of copper wires)

Figure 2: Diagnostic communication protocol stacks mapped to the OSI model.

BOTH IMAGES: SOFTING

A technical session at the 2023 SAE COMVEC event (*https://comvec.sae.org/program*) will highlight developments in diagnostics and prognostics for critical vehicle electronic systems. Topics will include the evolution of big-data techniques to promote prognostic development and case studies for zero-emission and autonomous vehicles. Panelists are expected from **DG Technologies**, **RA Consulting**, **Softing Automotive Electronics**, **VHM Innovations** and **Volvo Autonomous Solutions**.

Diagnostic communication

Figure 1 shows a simplified but typical setup of a diagnostic communication system. It consists of the external test equipment (TST), the Vehicle Communication Interface (VCI) and the E/E system of the vehicle. The E/E system consists of electronic control units (ECUs) that are connected via in-vehicle networks (IVN), but also of sensors, actuators, wiring and connectors. The VCI is connected to the E/E system of the vehicle via a Diagnostic Link Connector (DLC) as it is specified in SAE 1962 or SAE J1939-13.

Diagnostic communication is characterized by diagnostic service requests that are sent by the tester to the vehicle and diagnostic service responses sent from the vehicle to the tester.

L7	ISO 14229	SAE J1979-2	SAE J1979-3
L6			
L5			
L4 + L3	ISO 15765 (DoCAN)		
L2 + L1	ISO 11898 (CAN)		

Figure 3: UDS, OBDonUDS and ZEVonUDS are based on DoCAN / CAN.

Looking at a single temporal segment, it is seen that the communication always takes place between the single tester and exactly one ECU (TST-to-ECU, ECU-to-TST, peer-to-peer). For a successful communication, both TST and ECU must support the same communication protocol stack. As illustrated in Figure 2, a protocol stack consists of seven layers — for example, the Physical Layer (L1), the Transport Layer (L4) and the Application Layer (L7). Service requests and responses are specified on Layer 7.

For the communication between external test equipment — in this context also referred to as "OBD Scan Tool" — and the ECUs of the OBD system, legislative authorities such as CARB and the European Parliament / Commission mandate the support of a standardized diagnostic communication protocol stack. In the near future, tool-based diagnostics will include diagnostic communication with an OBD system that supervises the safety of the vehicle.

SAE J1979 and its "OBD Modes" have been in use for decades, but due to regulatory adoption of OBDonUDS, SAE J1979 now becomes a multiple-part document series. SAE J1979-3 for zero-emission propulsion systems defines ZEV as follows: traction drive motors and their inverters; energy storage systems; high-voltage charging systems (including components whose failures impact regenerative braking); and thermal control systems supporting propulsion (i.e., battery cooling pumps and sensors).

Figure 3 illustrates that the OSI Layers 1 thru 4 of the Application Layer protocols ISO 14229-1 (UDS), SAE J1979-2 (OBDonUDS) and SAE J1979-3 (ZEVonUDS) are the same: Diagnostics on CAN (DoCAN). Optionally, ISO 14229 and SAE J1979-3 (and ISO 27145 = World-Wide Harmonized OBD, or WWH-OBD) allow the diagnostic communication using DoIP and Ethernet.

Request SID	Service	Request SID	Service
0x10	Diagnostic session control *	0x31	Routine control *
0x11	ECU reset *	0x34	Request download
0x14	Clear diagnostic information	0x35	Request upload
0x19	Read DTC information *	0x36	Transfer data
0x22	Read data by identifier	0x37	Request transfer exit
0x23	Read memory by address	0x38	Request file transfer
0x24	Read scaling data by identifier	0x3E	Tester present *
0x27	Security access *	0x3D	Write memory by address
0x28	Communication control *	0x84	Secured data transmission
0x29	Authentication	0x85	Control DTC setting *
0x2A	Read data by peridoc identifier	0x86	Response on Event *
0x2C	Dynamically define data identifier *	0x87	Link control *
0x2E	Write data by identifier	0x2F	Input/output control by identifier

* marks services that are parameterized by a sub-function byte

Figure 4: ISO 14229 (UDS) Application Layer Services.

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J1979 SID	OBD II Mode	UDS Request	ISO 14229 SID
0x01	Request current powertrain diagnostic data	Read data by identifier	0x22
0x02	Request powertrain freeze frame data	Read DTC information	0x19
0x03	Request emission-related DTCs	Read DTC information	0x19
0x04	Clear/reset emission-related diagnostic information	Clear diagnostic information	0x14
0x06	Request on-board monitoring test results for specific monitored systems	Read data by identifier	0x22
0x07	Request emission-related DTCs detected during current or last completed driving cycle	Read DTC information	0x19
0x08	Request control of On-Board system, test or component	Routine control	0x31
0x09	Request vehicle information	Read data by identifier	0x22
0x0A	Request emission-related DTCs with permanent status	Read DTC information	0x19

Figure 5: Assignment of UDS requests to SAE J1979 OBD II test modes.

OSI-Layer 6	Content
SAE J1930 DA	Terms, Definitions, Abbreviations, Acronyms
SAE J1979 DA	Parameter Ids, Monitor Ids, InfoType Ids, Test Ids, Units and Scaling
SAE J2012 DA	Diagnostic Trouble Codes (DTCs) and Failure Type Bytes (FTB)
SAE J1939-71	Failure Mode Indicators (FMI)
SAE J1939 DA	Suspect Parameter Numbers (SPN)

Figure 6: SAE Recommended Practices referenced by SAE J1979-2 and -3.

Figure 4 shows the 26 Unified Diagnostic Services (UDS) as they are specified in ISO 14229-1. The services can be parameterized by sub-function bytes and/or Data Identifiers (DIDs). Figure 5 shows that the nine SAE J1979 OBD II Modes can be replaced by four ISO 14229-1 services. For example: OBD II Mode with the SID 0x09 = "Request vehicle information" and the PID 0x02 will be replaced by the UDS Request 0x22 = "Read data by identifier" and the 2-byte Data Identifier 0xF802. Both positive responses will contain the Vehicle Identification Number (VIN) of the vehicle.

Because ZEVonUDS covers vehicles with no emissions, the emission-related failures are replaced by ZEV propulsion-related failures. The OSI Layer 6 of both SAE J1979-2 and -3 reference several other SAE Recommended Practices and their Digital Annexes (DA) (see Figure 6).

J1979-2 and -3 differentiate two DTC (diagnostic trouble code) formats: SAE_J2012_DTCFormat_04 and SAE_J1939-73_DTCFormat. An ECU shall only support one DTC format. SAE J1979-2 and -3 are applicable for passenger cars with SAE J2012 DTCs as well as for heavy-duty trucks with SAE J1939 DTCs. If a vehicle or engine uses DTCs in the SAE J1939 format, they can be encoded using SAE J1939 SPNs (Suspect Parameter Numbers) as they are listed in SAE J1939 DA with FMIs (Failure Mode Identifiers) defined in SAE J1939-73 Appendix A.

The SAE J1979 OBD II Modes will be replaced by new UDS-based service requests. Even if the lower OSI model layers for both old and new protocol stacks remain the same, vehicle manufacturers and their E/E system suppliers as well as tool suppliers must upgrade their technology. A mixture of J1979 and UDS-based protocols is no longer allowed. This is a major step in the direction of finally having only one worldwide harmonized diagnostic protocol: UDS on IP.

Peter Subke, director business development at Softing Automotive Electronics GmbH, wrote this article for *Truck & Off-Highway Engineering*.

TESTING

Software-defined vehicles drive revamped design strategies

Automated driving, electrification, cloud computing and the push toward software-defined vehicles are forcing automotive and commercial-vehicle developers to revamp design strategies. Tools suppliers are moving to help engineers develop and verify solutions that address the complete vehicle environment, a task that requires a growing number of design tools.

During the recent **dSPACE** World Conference in Munich, Germany, several vehicle manufacturers described their strategies for coping with these trends. dSPACE, which supplies hardware/software-in-the-loop (HIL/SIL) tools, announced plans to see if tool makers can find a way to help developers by making it easier to integrate data created using different development software.

"Several companies are doing verification and validation tools, so it's a challenge to integrate everything into a seamless tool chain," said Carsten Hoff, CEO at dSPACE. "We want to invite companies to discuss creating an industry platform. We want to see if we as an industry can find the right consortium, with different companies contributing to make life easier for users."

dSPACE CEO Carsten Hoff detailed plans to see if some companies can work together to help users share data created using disparate design tools.

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