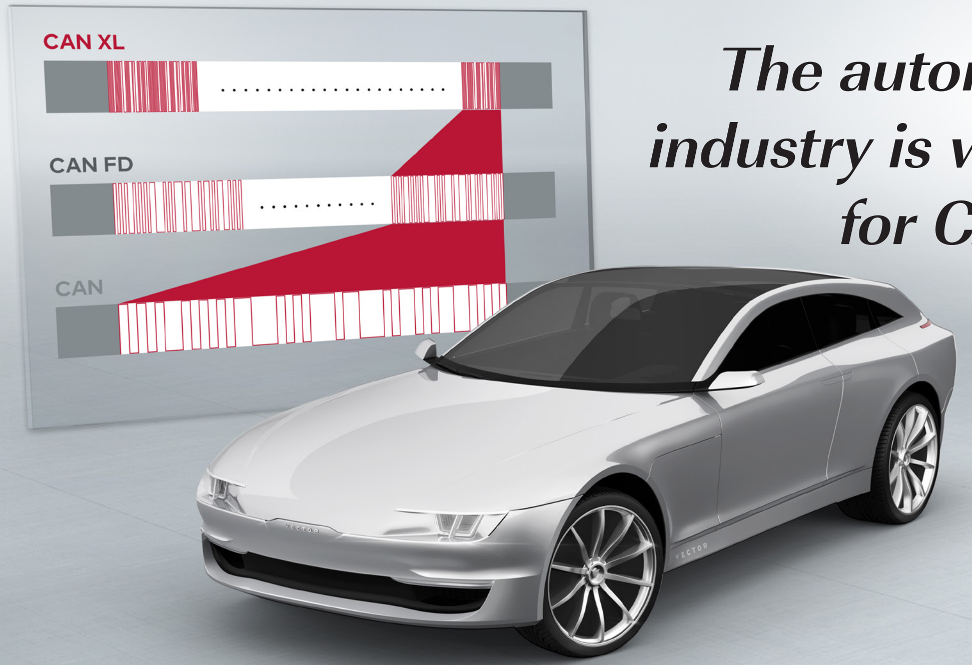
The automotive industry is waiting for CAN XL



(Source: Vector Informatik)

CAN XL contains many new impressive features, supports both signal-based and service-oriented communication, and is ideally tailored to future requirements. Numerous experts from the CAN industry met to exchange ideas on this topic at the Vector CAN Technology Symposium in Stuttgart at the end of October 2022.

After many online events recently, the symposium organized by Vector (the CAN Newsletter Online reported) as a face-to-face event offered international participants a welcome platform for direct exchange and intensive networking (Figure 1 and Figure 2). The thematic focus was on CAN XL, the third CAN generation that will play a significant role in shaping the E/E architectures of future vehicles. The program included a broad spectrum of presentations given by Bosch, CAN in Automation, Infineon, NXP, Renesas, STMicroelectronics, VW/Cariad, and Vector – as well as an accompanying exhibition. This article summarizes selected topics of the presentations.

Our mobility is currently undergoing fundamental changes, with electronic systems in motor vehicles gaining considerable importance. The trend favors centralization with high-performance computers (HPC) and zone controllers. ECUs (electronic control unit) and networks are no longer functionally divided into domains such as powertrain, chassis control, infotainment, and so on; instead, the focus is on zone architectures with subordinate networks (Figure 3). With up to 200 ECUs in a vehicle, the automotive industry must keep the costs for cabling, hardware, and software manageable. For this purpose, the Volkswagen group has founded the affiliated software company Cariad.

CAN XL increased to 20 Mbit/s

One of the main motivations for CAN XL is to bridge the bit rate gap between Classical CAN/CAN FD and Ethernet 100BASE-T1. On the other hand, even modern E/E architectures cannot do without fast signal-based communication, for example in real-time control circuits within zones. In this bit rate range, the 10-Mbit Ethernet version 10BASE-T1S is also available as a networking option.

With CAN XL, a sophisticated networking solution has been created, combining all essential requirements in one system. Thanks to a transfer rate of up to 20 Mbit/s, CAN XL easily meets the original requirement of ≥ 10 Mbit/s. It is (cost)-effective, robust, and real-time capable like the previous versions and, as a special feature, is also able to transmit external protocol information via tunneling. The latter primarily aims at enabling a service-oriented architecture for XL nodes as well. Ethernet tunneling also allows them to receive and transmit Ethernet frames – in addition to CAN XL messages, of course.

CAN XL: Technical details

Thanks to the features mentioned above, CAN XL is ideally suited for future automotive applications. On the one hand it is flexible, and on the other hand it provides important additions and innovations with regard to the protocol to implement the mentioned functionality. The CAN XL data field may now have lengths between 1 and 2048 bytes. This large user data length is required to tunnel Ethernet frames. In contrast to Classical CAN and CAN FD with identifiers of either 11 bits or 29 bits, CAN XL only uses 11-bit identifiers. This is fully sufficient, because – as will be shown below – CAN XL has quite a few new fields that provide more clarity and thus simplify handling. The restriction to the 11-bit identifier also increases robustness.

No changes have been made to the network access method; the CSMA/CR method (Carrier Sense Multiple Access/Collision Resolution) is still used. It provides a clear priority concept that allows the more important frame to be transmitted with no delays. The identifiers of Classical CAN and CAN FD include some important information such as priority, frame type, and source and destination addresses. ▷

Figure 1 + 2: 150 experts with international backgrounds welcomed the Vector Symposium in Stuttgart as a platform for information exchange and intensive networking (Source: Vector Informatik, photographer: Marc Feix Photography, Stuttgart)

This is a hindrance for large networks and high dynamics. Therefore, CAN XL defines a clear separation and introduces some new fields and new functions. The Arbitration field, for example, now contains only the priority.

The new fields and functions include the Acceptance Field, VCAN ID, SDU Type, Bit Stuffing, CRC (PCRC 13 bit and FCRC 32 bit), and Transceiver Mode Switching. While the SDT Field (Service-Data-Unit-Type) specifies the information in the Data Field (Figure 4), the SEC bit signals whether further layer-2 functions are applied, for example QoS or Security. The VCID Field allows the assignment of virtual CAN IDs. Up to 256 virtual networks can be defined within a single CAN XL network segment. They can be used to build up logical structures depending on how they are useful to make work easier. The AF (Acceptance Field) has a width of 32 bits and can be used for addressing. Source and destination addresses and also 29-bit identifiers can be stored.

CAN XL uses fixed stuff-bits, which are used in the data phase. As with Flexray, there are now two cascaded CRCs (cyclic redundancy checking) instead of just one for the detection of transmission errors. This provides very high transmission reliability with a Hamming distance of 6. The reliability of CAN XL frames has been independently verified by the Special Interest Group (SIG) CAN XL of Stuttgart and Kassel Universities. During the CAN Technology Symposium event, a video with the chairman of the Special Interest Group CAN XL at CAN in Automation, Mr. Dr. Arthur Mutter (Bosch), was recorded about CAN XL called "CAN XL - The next step in CAN evolution".

New physical-layer technologies

The symposium participants were given interesting insights into the processes on the physical layer, which is no longer a matter of bits and bytes, but of analog voltage characteristics. The transceivers are always responsible for generating the bus voltages. A fundamental requirement for transceivers is to be highly resistant against interference of all kinds, for example electrostatic discharge (ESD), and to emit little interference themselves. The performance of the transceiver type determines the bit rates a network can achieve. Therefore, CAN versions with increased or very high bit rates require better transceivers. Two new technologies are dominating current discussions on signal enhancement in this context: CAN SIC and CAN SIC XL. CAN allows complex topologies consisting of mixed line and star networks including long stubs, which naturally leads to reflections on the bus. Since ringing caused by reflections limits bit rates, this is where the improvements through SIC and SIC XL technologies must come into play.

With CAN SIC up to 8 Mbit/s

CAN SIC has been specified in the CiA 601-4 document by CAN in Automation (CiA). The goal is to actively dampen the ringing during transition from dominant to recessive. This allows the signal to reach a steady state more quickly, and it can be sampled correctly. Bit rates of up to 8 Mbit/s are possible even in networks with sophisticated topologies.

CAN SIC XL for 20 Mbit/s

For CAN XL transmission rates up to 20 Mbit/s, SIC XL transceivers are required. They also provide a special Fast mode in the data phase. While SIC XL uses SIC technology in the arbitration phase, a push-pull concept with alternating differential signal of ±1 V is used in Fast mode. Due to the lower differential voltage and the active driving of both levels, bit rates of 20 Mbit/s are possible.

Even experts are often unaware that there is no rigid link between the protocol and the type of transceiver. For CAN XL communication, all types of transceivers can be used. If a CAN FD transceiver is used for CAN XL, only the bit rate is limited to approx. 5 Mbit/s. Micro-controllers with CAN XL IP can handle automatically the Classical CAN, CAN FD, and CAN XL protocols. The controller just needs to be configured in the software. The resulting flexibility makes it much easier to switch from Classical CAN or CAN FD to CAN XL. The bit rate can be configured in the same flexible way. The usual speeds of 2 Mbit/s, 5 Mbit/s, 8 Mbit/s are merely limits. If any difficulties should arise with a network originally designed for 8 Mbit/s, the bit rate can easily be reduced, for example to 7,5 Mbit/s.

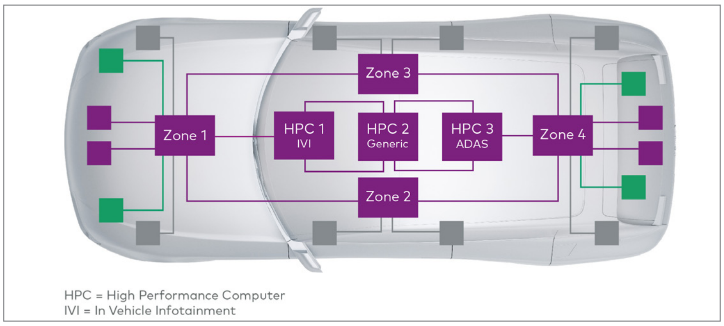


Figure 3: Possible future zone architecture in vehicles (Source: Vector Informatik)

SOF	Start of Frame	SBC	Stuff Bit Count
PID	Priority Identifier	PCRC	Preface CRC
RRS	Remote Request Substitution	VCID	Virtual CAN Identifier
IDE	Identifier Extension	AF	Acceptance Field
FDF	FD Format	Data	Data Field
XLF	XL Format	FCRC	Frame CRC
resXL	reserved bit XL format	FCP	Format Check Pattern
ADS	Arbitration-to-Dataphase Switch	DAS	Dataphase-to-Arbitration Switch
SDT	Service Data Unit Type	ACK	Acknowledge
SEC	Simple Extended Content	EOF	End of Frame
DLC	Data Length Code		

Figure 4 + Table 1: Detailed description of CAN XL frame (Source: Vector Informatik)

CAN XL meets Autosar

How do CAN XL and Autosar fit together? What are the main changes in Autosar? What effort is necessary to upgrade ECUs for CAN XL? As expected, concrete changes to the Autosar documents can mainly be found in the specifications for CAN transceivers, CAN drivers, and CAN interfaces, but also in the Ethernet interface specifications. CAN XL must now be definable as a physical medium for the Ethernet stack. For this, new configuration parameters have been defined. It must be possible to describe the CAN XL controllers in the ECU configuration. Existing value ranges such as bit rates, for example, must be adjusted. For this, these two new documents will be added: AUTOSAR_SWS_CANXLDriver and AUTOSAR_SWS_CANXLTransceiverDriver.

Modifications to the Autosar system template are required for the system description of the CAN XL-specific controller configuration. Frame triggering has been adapted for CAN XL frames and the new XL fields have been integrated. Fortunately, there is no need to change the description of signals and PDUs. For Ethernet frame tunneling, however, somewhat major changes must be made to the system template. Among other things, the responsible Autosar Concept Group has decided to introduce the Ethernet interface as a further upper layer for CAN XL. This allows access to the IP stack and service-oriented communication (SOME/IP, SOME/IP-SD). Consequently, IP communication via complex CAN topologies is now possible.

For a project update of a pure CAN ECU to CAN XL with unchanged communication description, adjustments are mainly necessary to the CAN interface and the driver layers. A more complex process, however, is the migration of an Ethernet ECU to a CAN XL ECU. New modules are added, especially because the ECU now needs a CAN interface and a CAN state manager even with pure Ethernet tunneling. However, this provides the advantage of using CAN and Ethernet communication on the same network. The CAN XL Autosar concept was approved in November 2022. A CAN XL product solution for the Autosar workflow is expected from Vector around mid 2023.

CANsec: Hardware-implementable security protocol

Another key requirement for future mobility is security. The new CANsec security protocol adds integrity, authenticity, and confidentiality to ECU communication. Without appropriate measures, it is basically quite easy to attack CAN. Since every CAN participant listens to all frames, it is sufficient to compromise a node to gain access to the communication. Attacks such as spoofing, sniffing, and message replay make the operation of engine controls, braking systems, and so on directly vulnerable. Autosar already has the SecOC security protocol, but this is at the top end of the protocol stack and places high demands on CPU performance.

The CANsec protocol provides the solution. Preferably implemented in hardware, it works efficiently and fast. Both sender and receiver have secret keys that must be transferred to the devices beforehand in a secured way. The AES (advanced encryption standard) generator on the CANsec controller encrypts the frame to be sent and provides it with the Integrity Check Value (ICV) and verification information. If the receiver calculates the same ICV value during decryption, data transmission was done correctly. CANsec allows secure zones to be formed from several participants. Their communication can now no longer be interpreted by other participants on the same network segment. CANsec is fully implementable in hardware and software to enable smooth migration to the next vehicle platforms.

Small and smart: CAN FD Light

CAN FD Light is a simple but efficient networking system derived from CAN FD. Unlike all other CAN versions, the commander-responder principle is used here, similar to ▷

LIN. Since only a limited number of nodes are to be controlled, 11-bit identifiers are sufficient. There is no bi-trate switching, the data rate always corresponds to the arbitration data rate. CAN FD Light uses exclusively CAN FD frames because they offer clear advantages over Classical CAN with their user data length of 64 byte. CAN FD transceivers according to standard ISO 11898-2 are provided for the bus structure.

CAN FD Light protocol controllers for responder nodes are housed in a single monolithic IC. On the responder side, no more software is required. The responders' memory addresses are accessed directly. In addition to addressing individual participants, many responders can be addressed simultaneously via multicast and broadcast frames. On the commander side, a conventional CAN FD controller is used. CAN FD Light thus offers a cost-effective solution for query sensors and controlling many small actuators.

Existing CAN FD know-how, analysis tools, and interfaces can be reused almost unchanged for CAN FD Light. The SIG of CiA is responsible for standardization, design recommendations, and conformance testing. The CAN FD Light specification on the part of CiA has been completed; ISO standardization as a normative annex for ISO 11898-1 is in progress.

Summary and perspectives

CAN XL, which has been further developed on the basis of Classical CAN and CAN FD, scores with several innovations and is ideally tailored to the requirements of future E/E zone architectures. New fields in the protocol provide more clarity and facilitate software development. On the physical layer, the new CAN SIC and CAN SIC XL technologies significantly increase transmission speed up to 20 Mbit/s.

One of CAN XL's outstanding features is the tunneling of Ethernet frames. This allows both signal-based real-time communication and service-oriented communication via the same network. Consequently, CAN networks with complex technologies are also available for IP communication. Multi-drop architectures connect multiple participants without switches and save costs on cable harnesses. On the software stack side, any CAN XL ECU can be turned into an Ethernet endpoint and allow service-oriented communication there as well. CAN XL thus also offers good prerequisites for the migration of various higher protocols. The first controller prototypes are expected to be distributed to OEMs (original equipment manufacturers) by semiconductor manufacturers in mid 2023, so the first CAN XL controllers could be freely available by mid 2024. ◀

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