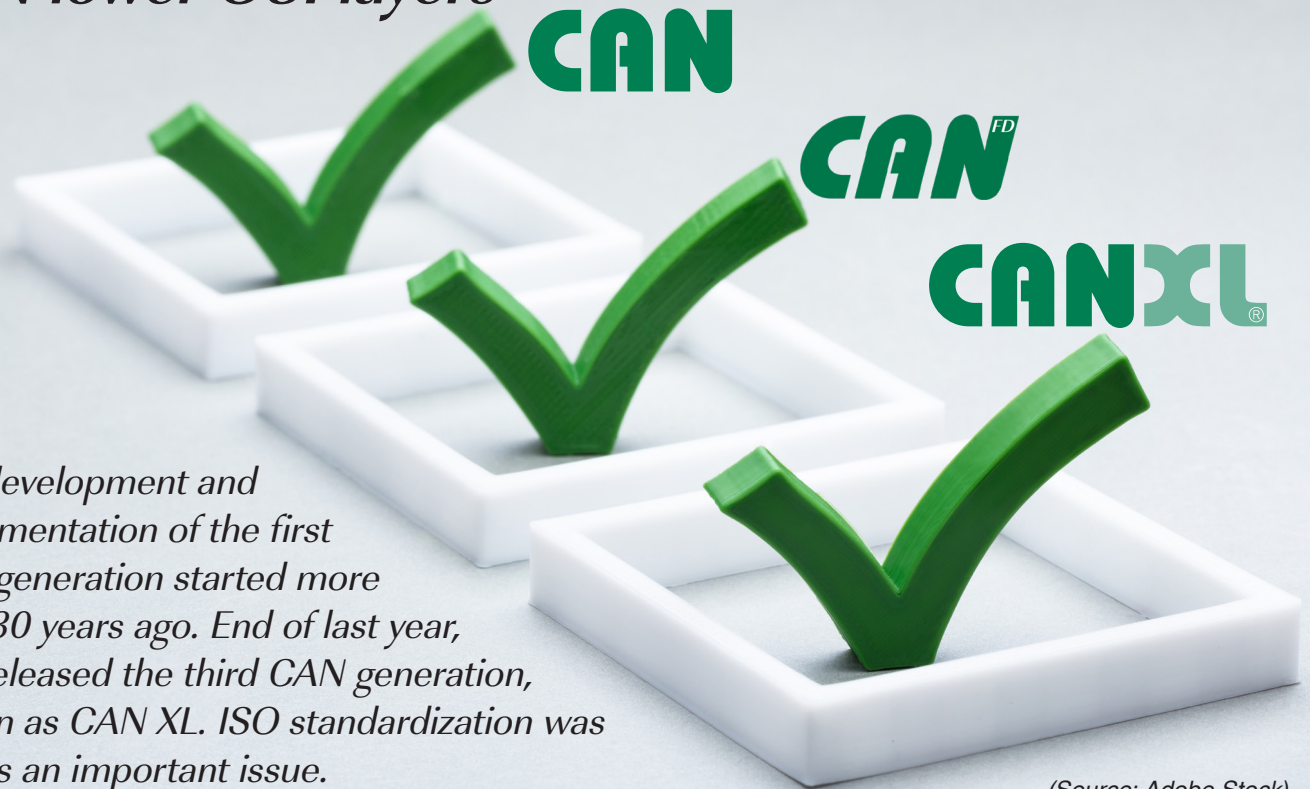*History and trends:*

CAN lower OSI layers

The development and implementation of the first CAN generation started more than 30 years ago. End of last year, CiA released the third CAN generation, known as CAN XL. ISO standardization was always an important issue.

(Source: Adobe Stock)

The seven-layer Open Systems Interconnection (OSI) model was developed in the late 1970s. It describes the flow of data to be transmitted to receivers through seven abstract layer entities. Nowadays, the OSI model is used to describe communication in a unique manner. CAN communication technology covers just the two lower layers, the data link layer and the physical layer. The fathers of CAN at Bosch did not care so much on the OSI layer modeling. This is, why the Bosch CAN 2.0 document did not specify services and service access points (SAP) between the data link sub-layers and the physical sub-layers. In the beginning, the CAN protocol featured an 11-bit identifier (ID) field; the 29-bit ID field was introduced in a second step, also known as CAN 2.0B. CAN 2.0A controller chips not supporting the 29-bit frame format were available only for some years.

End of the 80s, Intel and Philips Semiconductors (today: NXP) implemented the CAN data link layer and the PMA sub-layer in silicon. Intel's i82526 and Philips' 82C200 stand-alone CAN controllers are legend. In these early days, no standardized transceiver was available. The first CAN node designers used proprietary modified EIA 485 circuitries.

The first CAN generation

In 1993, the CAN data link layer (DLL) was internationally standardized in ISO 11898 (1st edition). This standard covered both CAN protocol versions, CAN 2.0A and CAN 2.0B. It split the DLL in two sub-layers, the logical link con-

trol (LLC) and the medium access control (MAC) sub-layers. This modeling was adapted from Ethernet. The ISO 11898 standard also introduced service specifications for these sub-layers describing implicitly SAPs. As the CAN 2.0A/B specification, this ISO standard also comprised the physical coding sub-layer (PCS), which is part of the OSI physical layer. The original ISO 11898 standard also included the physical medium attachment (PMA) sub-layer, which is implemented in CAN transceiver chips. First CAN high-speed transceiver engineering examples arrived in 1992. The first demonstration of ISO 11898 transceivers was done by CiA members on the joint booth of the Interkama tradeshow in October 1992. They used the transceivers from Philips Semiconductors (now: NXP).

Mid of the 90s, an increasing number of chipmakers launched CAN stand-alone controllers as well as CAN controllers integrated into micro-controllers. Just to name a few: Besides the early birds, Intel and Philips Semiconductors, Motorola (now: NXP), National Semiconductor, and Siemens (now: Infineon) entered the CAN controller business. The CAN (high-speed) transceiver market was dominated from the beginning by Philips Semiconductors (now: NXP). Of course, other chipmakers offered pin-compatible components, for example, Siliconix and Texas Instruments.

End of the 90s, General Motors developed the Single-wire CAN (SWC) transceiver standardized in SAE 2411. The speed is limited to a nominal bit rate of 33,3 kbit/s respectively to 83,3 kbit/s in the so-called high-speed mode for diagnostics purposes. Up to 32 CAN nodes per network are possible. The SWC transceiver provide sleep ▷

functionality. Due to the single-wire approach, there is no differential voltage on the network-line. This leads to a lower robustness compared with the ISO standard. Therefore, SWC is not more recommended for new designs.

Beginning of the millennium, the ISO 11992-1 standard was published. It specified a dedicated PMA sub-layer for the CAN truck/trailer connection, which is able to drive two nodes. Unfortunately, the standard has had some weaknesses and was not implemented, but referenced by European regulation. Wabco (now: ZF) implemented a technical improved CAN transceiver, which was not available on the public market. The 3rd edition of ISO 11992-1 released in 2019 has fixed the technical issues and is harmonized with the ZF transceiver features. The ZF transceiver is also used by the competitor Knorr-Bremse.

In 2003, ISO 11898 was split into two documents: ISO 11898-1 (2nd edition) and ISO 11898-2. The updated standards specified the Classical CAN data link layer including the PCS sub-layer respectively the high-speed PMA sub-layer for bit rates up to 1-Mbit/s.

The carmakers requested a low-power CAN transceiver, which was standardized in 2006 as ISO 11898-3. The drawback of this fault-tolerant transceivers was the to 125 kbit/s limited speed. This was the trigger to develop the low-power option for high-speed transceivers standardized in ISO 11898-5 released in 2007. In 2013, high-speed transceivers compliant with ISO 11898-2 with selective wake-up functionality (ISO 11898-6) saw the light of day. The idea was to bring not needed electronic control units (ECU) into sleep mode and to awake them individually, when necessary. But the success was not that overwhelming, which may change in the next years.

The second CAN generation

CAN with flexible data-rate (CAN FD) was pre-developed by Bosch on demand of General Motors and non-automotive CAN users represented by CiA desiring more bandwidth and larger frame payload. Especially, the carmakers were interested to reduce software download times at end-of-line. To flash the ECUs (electronic control unit) via CAN within the cars took in worst case several hours. Even to cut this time only by half is already a huge success.

During the CAN FD standardization, there were detected some problems in the detection of single-bit failures. The introduced stuff-bit counter and the following parity bit solved this issue as well as the properly selected initial value for the cyclic redundancy check (CRC) sequences. At the end, CAN FD features a lower probability of undetected failures than Classical CAN. The 3rd edition of ISO 11898-1 released in 2015 standardized both the Classical CAN and the CAN FD protocols. One year later, ISO updated the high-speed PMA sub-layer introducing more challenging parameters to allow bit rates higher than 1 Mbit/s. This included symmetry requirements for rising and falling signal edges. There were two parameter sets standardized. CiA recommends using transceivers ▷

The CAN FD Light approach provides a commander/responder communication solution for price-sensitive networks used for example in smart headlights (Source: Adobe Stock)

featuring the more symmetric edges. This allows to use not optimized network topologies and still to achieve bit rates of 2 Mbit/s and more. ISO 15765-5 standardizes the bit-timing for CAN FD point-to-point networks used to connect a diagnostics tool to the in-vehicle network gateway. CiA provides general guidelines for the CAN FD bit-timing settings.

In order to reduce ringing caused by not optimized network topologies, CiA members developed the signal improvement capability (SIC) transceiver specification (CiA 601-4). In the meantime, several semiconductor manufacturers provide such SIC transceiver.

There was another demand from the automotive industry to use CAN FD in a commander/responder communication without arbitration. As a consequence, this leads to responder nodes, which do not need costly add-on circuitry such as oscillators. The tradeoff is that only the commander can initiate a communication. The responders just answer the communication request. CiA members developed the CAN FD Light specification (CiA 604-1) suitable for responder nodes. First implementers are STMicroelectronics and Texas Instruments. Applications include smart headlights controlling a bunch of LEDs. Another application field is the internal networking of battery cells. CAN FD Light is a candidate for an annex of ISO 11898-1; so-to-say a dedicated implementation of CAN FD. The CAN FD Light approach has some technical similarities with the Classical CAN serial link I/O (SLIO) concept, which was commercially not successful. Philips Semiconductors (now: NXP) launched the first SLIO component in the very early 90s; but the time was not yet ripe. A few years later, LIN was developed and introduced. CAN FD Light is a candidate to substitute LIN, because of higher bit rates (1 Mbit/s and more) and larger payloads (up to 64 byte). CAN FD Light is a candidate to be used instead of LIN, when higher bit rates and more payload is needed.

The third CAN generation

Surprisingly, just four years after the introduction of the second CAN generation, the third CAN generation was initiated. Volkswagen (VW) requested extra-long (XL) frames able to transport TCP/IP segments/packets with 10 Mbit/s. In 2019, CiA started the development of related CAN XL specifications. End of 2021, the CAN XL data link layer (CiA 610-1) and the CAN XL physical medium attachment sub-layer (CiA 610-3) were released. In the next step, these documents will be integrated into the ISO 11898-1 respectively ISO 11898-2 standards.

CAN SIC XL transceivers can support bit rates up to 20 Mbit/s. The maximal achievable bit rate depends on the network topology and the selected physical layer components such as cables and connectors. Additional circuitry to improve electromagnetic compatibility (EMC) or galvanic isolation has an impact on the bit rate, too.

The cascaded CRC fields, the fixed stuff-bits, and the other CAN XL protocol features makes the third CAN generation to the most reliable one. The robustness of the CAN XL communication is in minimum as high as in Classical CAN and CAN FD. One of the important features is the scalability of the PMA sub-layer. CAN XL controller can work with all kinds of CAN high-speed technologies.

It seems that the CAN XL technology is already mature. The first CAN XL plugfest was a success and there more such interoperability tests in the pipeline. First CAN XL supporting micro-controllers are under development. CAN SIC XL transceiver prototype implementations have been tested in the mentioned plugfest and others will follow.

The future for all three CAN generations seems to be bright. Depending on the application requirements, the user can choose a CAN protocol (Classical CAN, CAN FD, or CAN XL). Selecting CAN FD or CAN XL gives the user another level of scalability regarding the transceiver technology as explained above. This makes CAN technology very suitable for sub-backbone and front-end networking, where reliability and robustness matters. The traditional reasonable prices for the hardware are important for high-volume applications.   ◄

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