2025

Controller Area Network

CAN CC – CAN FD – CAN XL

1986
2015
2021

CAN CC (classic): up to 8-byte data fields and up to 1 Mbit/s

CAN FD (flexible datarate): up to 64-byte data fields and up to 8 Mbit/s

CAN XL (extended data-field length): up to 2048-byte data fields and up to 20 Mbit/s

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CAN CC: The classic CAN protocol as launched in 1986

CAN CC protocol features

CAN CC specifies data/remote frames in CBFF (classic base frame format) as well as CEFF (classic extended frame format), error frames, and overload frames. The unique contention-based arbitration method enables network access for the highest prior data/remote frame with no delay. The provided error detection mechanisms guarantee a very low residual error probability. All single bit errors are detected. Faulty data/remote frames are re-transmitted automatically. This leads to a very reliable communication. The implemented fault confinement enables permanent faulty nodes to be logically disconnected from the network. The data field length of data frames is 0 byte to 8 byte.

CAN CC physical layer options

The possible bit rate depends on the network overall length. The maximum bit rate is 1 Mbit/s at network length of about 25 m. There are several physical medium attachments (PMA) specified (implemented in transceiver chips). Most implemented is the CAN HS (high-speed) PMA as standardized in ISO 11898-2. It supports nominal (arbitration) bit rates up 1 Mbit/s, some of them are limited to 40 kbit/s at the lower end. CAN HS transceiver use differential voltages, making the communication highly robust. Some CAN HS transceivers support a low-power mode or a selected wake-up capability. Other physical layer options include a fault-tolerant (FT) transceiver (ISO 11898-3) and a special-purpose transceiver for towing and towed commercial vehicles (ISO 11992-1). They are restricted to bit rates of 125 kbit/s, in maximum.

CAN CC applications

For more than 30 years, CAN CC was the dominating CAN protocol version. It was applied to many application fields. Per year, there are still installed far more than two billion CAN nodes. This high volume leads to very reasonable hardware costs for CAN nodes. The most important application is in-vehicle networking in passenger cars. But there are also high-volume applications in light electric and commercial vehicles (on- and off-road). Other important application fields include (in alphabetic order) agri-food systems, airborne and satellites, elevator control, embedded machine automation, maritime electronics, medical devices, rolling stock, vending machines, etc.

CAN FD protocol features

CAN FD specifies data frames in FBFF (FD base frame format) and FEFF (FD extended frame format). Remote frames are not supported at all. Error and overload frames are as in CAN CC. The error detection capabilities are similar to CAN CC, meaning the residual error probability is even a little bit lower. All single bit errors are detected. The contention-based arbitration method is the same as in CAN CC. One of the improvements is the length of the data field: from 0 byte to 64 byte. (Note: The length is not byte-wise increasable).

Remark: There is also the CAN FD light protocol specified in ISO 11898-1:2024. This is a commander/ responder communication schema based on the CAN FD protocol for price-sensitive applications.

CAN FD physical layer options

CAN FD frames are transmitted in two phases: arbitration and dataphase. They can use different bit rates. The nominal (arbitration) bit rate is limited to 1 Mbit/s. In the dataphase, it can be increased, depending on the applied transceiver technology. CAN FD transceiver enable bit rates of 2 Mbit/s and in case of point-to-point links up to 5 Mbit/s. Using CAN SIC (signal improvement capability) transceivers, suppressing the ringing on the bus lines, allow dataphase bit rates of up to 8 Mbit/s, depending on the physical network design (topology, cables, etc. CAN SIC transceivers can achieve in the arbitration phase only bit rates up to 667 kbit/s. In general, the physical layer design of CAN FD networks is more challenging compared with CAN CC networks.

CAN FD applications

The automotive industry has applied CAN FD in-vehicle networks since the year 2020. In the meantime, several billion CAN FD nodes have been installed. However, the automotive industry is still in the process of migrating from CAN CC to CAN FD. Increasingly, CAN SIC transceivers are applied. In non-automotive applications, CAN FD networks are not installed in volumes, yet. In general, the enlarged data field in CAN FD data frames is needed, when functional safety and cybersecurity higher-layer protocol extensions are desired. CAN FD is already in some deeply embedded non-automotive in use. CiA expects a significant CAN FD market penetration in the next couple of years. Additionally, CiA expects CAN FD light applications, when CAN FD light responder chips are available.

CAN XL protocol features

CAN XL specifies data frames in XLFF (XL frame format). They use separated fields for bus arbitration (priority field) and content identification (32-bit acceptance field). Remote frames are not supported. Error and overload frames are as in CAN CC and CAN FD. XLFF data frames embed higher-layer management information such as the SDT (service data unit type) and the VCID (virtual CAN network ID). There is also the SEC (simple/extended content) bit, which can be used to indicate the support of add-on functions such as the CANsec cybersecurity protocol or the frame fragmentation method. XLFF data frames feature a “true” hamming distance of 6, meaning five randomly distributed bit error are detected. The frame transmission reliability is even higher compared with CAN FD and CAN CC. The data field length is specified from 1 byte to 2048 byte.

CAN XL physical layer options

CAN XL data frames are transmitted in two phases like CAN FD data frames. You can use CAN HS, CAN FD, and CAN SIC transceivers. Additionally, it is possible to use CAN SIC XL transceivers. In this case, the CAN XL protocol controller uses in the dataphase the FAST mode instead of the SIC mode. In FAST mode, the voltage levels are different, but still differential. In FAST mode, the maximum bit rate is 20 Mbit/s depending on the physical network design (e.g., topology). The transition from SIC to FAST mode is performed in two steps, in order to meet EMC (electromagnetic capability) of the automotive industry. When applying SIC or SIC XL transceivers, the nominal bit rate is limited to 667 kbit/s.

CAN XL applications

Currently, CAN hardware (CAN XL protocol controllers and CAN SIC XL transceivers) is not provided in production volumes, yet; but engineering samples are available. CAN XL is expected to be used in passenger cars for price-sensitive in-vehicle networking, end of this decade. The data field length of up to 2048 byte enables an easy integration into software-defined vehicle (SDV) network architectures. Non-automotive users have already indicated interest in CAN XL, too.

CAN in Automation (CiA) international users' and manufacturers' group

CiA has been established in March 1992. The non-profit association provides technical, product, and marketing intelligence information. The aim is to promote CAN technology's image and to provide a path for future developments. Therefore, CiA takes part in and supports the development of CAN-related standards and specifications. Additionally, an important part of the organization's effort is spent to develop and maintain specifications for CAN-based higher-layer protocols such as, CANopen and J1939.

CiA members develop and maintain the CAN ecosystem. This covers the data link layer, the physical layer, and higher-layer protocols as well as application, device, and interface profiles.

CiA organizes worldwide joint marketing activities This includes joint stands at tradeshows, joint information events, workshops, and contributions to magazines as well as conferences. An essential aim of the organization is the social networking of CAN-interested parties. In CiA's technical and marketing groups, engineers can exchange experiences and knowledge.
CiA's contributions include:

- Coordination and support of ISO 11898 standard series maintenance, and other CAN-related standards in international and national standardization bodies.
- CiA technical groups develop specifications or technical reports to increase the CAN device interoperability.
- Interoperability testing (so-called CiA plugfests) to check interoperability of CAN lower-layer products (protocol controller and transceiver).

CiA CAN lower-layer technical documents

- CiA 102 (version 3.1.0), CAN physical layer for industrial applications
- CiA 103 (version 1.1.0), Intrinsically-safe CAN device interface
- CiA 106 (version 1.1.0), Connector pin-assignment recommendations
- CiA 110 (version 1.1.0), CAN common mode choke
- CiA 601-1 (version 2.0.0), CAN FD node and system design - Part 1: Physical interface implementation
- CiA 601-3 (version 1.0.0), CAN FD node and system design - Part 3: System design recommendations
- CiA 601-6 (version 1.0.0), CAN FD node and system design - Part 6: Cable
- CiA 611-1 (version 2.0.0), CAN XL higher-layer functions - Part 1: Service data unit types

Remark: CiA is working on a CAN SIC XL simulation model specification (CiA 910 series).

CAN: Not only an embedded network for automotive applications

CAN is a serial network technology, providing dedicated features needed for in-vehicle networks. This includes:

- *Robust communication in harsh environments*
  The CAN physical medium attachment uses differential voltages, which makes the transmission of NRZ-coded (non-return to zero) respectively PWM-coded (pulse-width modulation) symbols robust. The CAN lower-layer hardware features a minimum temperature range from -40 °C to +125 °C.
- *Reliable frame transmission and fault confinement*
  Error detection by means of CRC (cyclic redundancy check), bit stuffing, etc. enables a very low probability of undetected bit errors. The automatic retransmission of faulty data/remote frames ensures a network-global data consistency. The fault confinement function avoids that a permanent faulty CAN node can disturb the communication of the other nodes by means of entering the bus-off state.
- *Deterministic communication*
  CAN's non-destructive arbitration supports determinism and predictable latency. Even under high bus load, the highest prior data frame gets access to the network without any delay. This essential for real-time systems.
- *Cost-effective hardware*
  CAN protocol controllers, often on-chip in microcontrollers, are available for reasonable costs. This reduces bill of materials (BOM) cost compared to other serial communication technologies.
- *Long-term availability and ecosystem*
  CAN is supported by many semiconductor vendors. Its mature ecosystem ensures tool and software availability—making it ideal for industries with lifecycles beyond 15+ years (e.g., railway, medical, and avionics).
- *Flexible for designers; transparent for operators*
  Designers benefit from modular, scalable architectures and strong tool support. Operators value diagnostic capabilities, network robustness, and ease of maintenance—even in systems running 24/7 over decades.

International standards

- ISO 11898-1:2024, Road vehicles – Controller area network – Part 1: Data link layer and physical coding sublayer
- ISO 11898-2:2024, Road vehicles – Controller area network – Part 2: High-speed physical medium attachment (PMA) sublayer
- ISO 11898-3:2006, Road vehicles – Controller area network – Part 3: Lo-speed, fault-tolerant, medium-dependent interface
- ISO 11992-1:2019, Road vehicles – Interchange of digital information on electrical connections between towing and towed vehicles – Part 1: Physical and data link layers

CAN in Automation e. V.
Kontumazgarten 3
DE-90429 Nuremberg
Phone: +49-911-928819-0
Fax: +49-911-928819-79
headquarters@can-cia.org
www.can-cia.org