History and trends:

From classic CANopen to CANopen FD

The CANopen application layer was developed under the umbrella of a European research project. In the last three decades, it has penetrated many application fields. CAN in Automation (CiA) has released more than 20 000 pages of CANopen profile specifications.

The predecessor of CANopen, was the CAN Application Layer (CAL) specified by CiA members in 1992. Because the CAL specifications were very academic based on the OSI reference model, the ASPIC (Automation and Control System for Production Units and using an Installation Bus Concept) European research project was launched. Bosch led it and mayor contribution came from the University Newcastle (UK). The project participants introduced dedicated application layer protocols and a communication profile. This included the CANopen dictionary with a 16-bit index and an 8-bit sub-index addressing method for parameters. The communication parameters were assigned to the index range from 1000_h to $1FFF_h$. In the range 6000_h to $9FFF_h$, process data, application configuration, and diagnostic information of standardized profiles are available. Proprietary application parameters use the index range from 2000_h to $5FFF_h$. The research results, about 30 pages, were handed over to CiA for further development and maintenance.

The history: Classic CANopen

End of 1994, CiA released the first version of the CANopen application layer and communication profile, which was updated just two months later. Version 2.0 was the base for the first CANopen demonstrator exhibited on the Hanover Fair CiA booth in 1995. In the beginning, the name "CANopen" and the document number "CiA 301" were not used. But from version 3.0, this CAN-based application layer and communication profile was published in the CiA 301 document. This version was implemented in the first commercially available CANopen devices. In the beginning, IEC 61131-compliant programmable logic controllers (PLC) were rare. CANopen host controllers were mainly embedded control devices programmable in computer languages such as C and C++. But actuator and sensor manufacturers provided increasingly CANopen interfaces for their products. Embedded host controllers not fully compliant with CiA 301 were able to control and manage these CANopen products. Many of them did not provide an object dictionary. The disadvantage: They could not be diagnosed via the CAN network.

Of course, there were some misunderstandings of the CiA 301 specification. Many engineers thought and some still do it today that the pre-defined connection set of CAN identifiers comprising a 4-bit function code and a 7-bit node-ID have to be

Figure 1: CAN in Automation has released more than 20 000 pages of CANopen profile specifications (Source: CiA)

used. The truth is that only the Default SDO client message, the Heartbeat messages, and the NMT message have fixed function codes. All other CANopen messages can be configured with all not restricted 11-bit CAN identifier values. Details are given in CiA 301.

Another misinterpretation is that the SYNC and the TIME messages need to be send by the CANopen host controller. Correct is that any CANopen device can do it. The system designer has to take care that there is a consistent assignment of the producing and consuming CANopen devices. There are also misunderstandings caused by not often implemented features. A feature could be specified, but nobody has implemented it. This does not mean that this feature is not provided by CANopen.

Some people think that CANopen is complex. But it is not. It is more complex to specify all the CANopen functions by yourself. CANopen specifications are like menus: You need to order and eat only what you like. You don't have to take all offered meals.   ▷

From CANopen version 4.0 onwards, four PDOs to be transmitted and four PDOs to be received can be assigned with a pre-defined CAN identifier. This version also introduced the Boot-up message using the same fixed (not configurable) CAN-ID as the Heartbeat message. In version 3.0, some device manufacturers misused the EMCY message as a boot-up indication.

CiA does not recommend to use CAN remote frames at all. Therefore, NMT node-guarding and remotely requested PDOs are not longer state of the art. It is also not recommended to change the bit-timing parameters and the node-ID number by means of SDO services in the CANopen object dictionary, because this could lead to severe network problems. If you like to configure them via the CANopen interface, layer setting services (LSS) should be used as specified in CiA 305.

The success: Profile specifications

The first CANopen device profile released specified the process data and configuration parameters for input/output (I/O) modules. This specification is known as CiA 401 and covers digital and analog I/Os. Besides this very generic profile, CiA members developed the CiA 402 profile for (electrical) drives and motion controllers. This was and is one of the most successful CiA profile specifications. In the meantime, it is internationally standardized in the IEC 61800-7 series. It has been adapted also by other communication technologies, especially Ethercat. There are also profiles for encoders (CiA 406) and inclinometers (CiA 410), which are used in very different applications fields. They range from textile machines via pitch control in wind-power systems and medical scanner devices to cranes and construction machines – just to name some of the important ones (see insert "CANopen application stories").

CiA has specified also application-oriented profiles. The CiA 417 series, for example, specifies elevator control systems. The CiA 422 series internationally standardized in EN 16815 describes the CANopen interfaces for refuse collecting vehicle equipment. There are still some unused treasures in the CiA profile portfolio. In total, the CiA profile specifications comprise more than 20 000 pages. There are also profiles developed jointly or even outside of the CiA community. The CiA 420 series of profiles for extruder downstream devices has been published with nonprofit Euromap association for plastics and rubber machinery manufacturers. DIN has released the DIN 14700 series of CANopen-connectable fire-fighting equipment. This German standard is under review and will be published in English language. Another jointly developed profile family is CiA 454: Together with Energybus members, these documents have been submitted partly for IEC standardization. The IEC standards specify the charging of light electric vehicles (LEV) in public infrastructures. The CiA 454 profile covers additional power management devices, too.
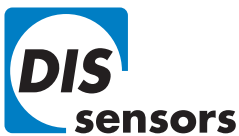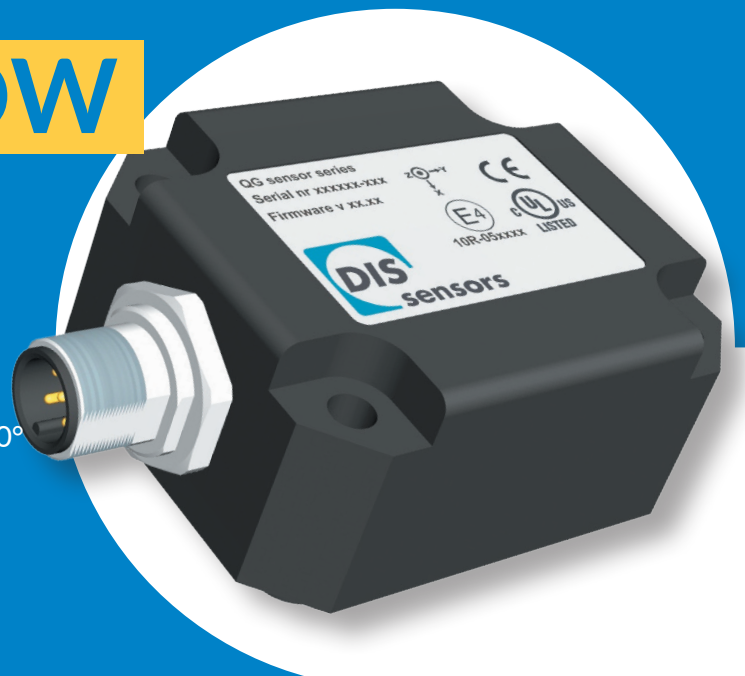
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The CiA profile specifications are also mappable to other communication technologies. Therefore, CiA split its updated and reviewed profile specifications into an application layer independent part describing only the application parameters. The mapping to the CANopen and the CANopen FD application layers is provided in separate documents. This includes also the requirements on the communication parameters.

CiA has also mapped its encoder and inclinometer profiles to J1939. In future, other CiA profiles may also be mapped to the J1939 application layers depending on market requests.

The future: CANopen FD

Classic CANopen is limited by the Classical CAN data link layer and the CAN high-speed physical layer regarding the network throughput. This is caused by the maximum bit rate at a given network length and the 8-byte data field limit requiring a transport layer protocol for larger data, which needs some protocol overhead. To overcome these limitations, the CAN community has developed the CAN FD data link layer (ISO 11898-1:2015) and the CAN SIC transceiver specification (CiA 601-4). CiA members have also improved CANopen, in order to use the new features of CAN FD, especially the longer data field with up to 64 byte. CANopen FD (CiA 1301) provides also an extended Universal SDO functionality, which allows to use pre-defined USDO clients in every device. This means USDO communication is possible between all connected CANopen FD devices.

CANopen FD protocol stacks are available from different vendors (Emotas, Emsa, and Microcontrol). Microcontrol and Peak provide very first CANopen FD products: host controllers and I/O devices. Most of the earlier adopters use CANopen FD as embedded networks and not as open network solution. They regard this is a secret and do not provide public information about such first CANopen FD applications.

CANopen FD can also be mapped to CAN XL, the currently submitted third CAN protocol generation for ISO standardization. An SDT (service data unit type) value needs to be assigned. The 8-bit SDT is the next implemented higher OSI layer indication embedded in the CAN XL data link layer protocol. In conjunction with 8-bit VCID (virtual CAN network ID), you can run up to 256 CANopen FD applications in parallel on a single network segment. Of course, you can also use on the same cable J1939-22 applications indicated by another SDT value. This allows the usage of CAN XL as a backbone network in applications, in which different higher-layer protocols are used. This includes also TCP/IP solutions.

To map CANopen FD to CAN XL requires additionally an assignment of communication services to the 32-bit acceptance field and how to use the 11-bit priority identifier. This is in the scope of the CiA IG (interest group) CANopen

CANopen application stories

The list of CANopen application examples is very long. In the last three decades, CANopen has been used as embedded control network, in machines on wheels, in elevators, in medical and laboratory equipment, in rail vehicles, and in maritime electronics, for example. The most exotic applications include embedded networks on the ocean ground and in satellites. The CAN Newsletter has reported about some of them:

- Textile industry: Haircut with a hot flame
- Traffic light: Panel PC with four CANopen interfaces
- Silicon wafer production: Multi-axis system for solar industry
- Healthcare: Tumor treatment with a CANopen motor
- Farming: Milking robot
- Beverage production: Filtration process for improved drinks
- Construction machines: Automatic leveling system for graders
- Satellite: CAN in the outer space
- Maritime electronics: Sensors for ship cranes
- Commercial vehicles: Battery charger for on-board integration
- Elevator control: Hydraulic car drive
- Municipal vehicles: Automated sewer cleaning with CANopen

Classic CANopen is still used in many new network applications. The provided communication services are sufficient for many embedded networks. 'CANopen' and 'CANopen FD' are European Community trademarks by CAN in Automation.

FD and will be introduced in one of the next versions of the CiA 1301 specification.

Because CAN XL hardware such as protocol controllers and transceivers compliant with CiA 610-1 respectively CiA 610-3 is not yet available, there is no hurry to release the CAN XL extension for CANopen FD. First micro-controllers supporting CAN XL will be launched mid of the 20ies. CAN SIC XL transceivers are expected a little bit earlier. Prototypes have been tested already in the first CAN XL plugfest organized by CiA in summer 2021 as well as FPGA implementations of CAN XL protocol controllers. Another plugfest took place in May, 2022. ◄

Author

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org
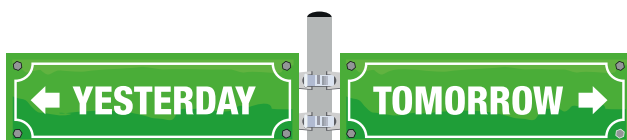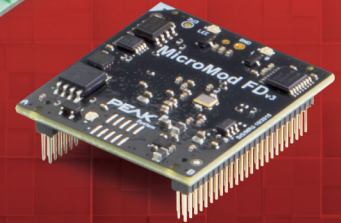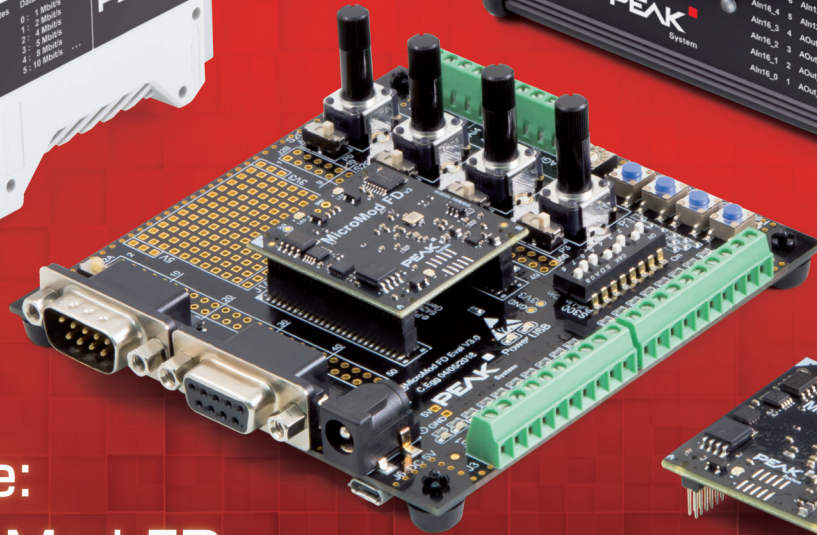
Product Line: PCAN-MicroMod FD

■ I/O Modules with CAN FD & CANopen FD

The PCAN-MicroMod FD is a plug-in board that provides a CAN FD interface and I/O functionality for the integration into your hardware. An evaluation board facilitates developing your custom solution. The modules are configured with a Windows software via CAN and then operate independently.

Ready-to-Use Motherboards

The PCAN-MicroMod FD is available with motherboards providing peripherals for specific applications.

Common Features:
- Board with plugged on PCAN-MicroMod FD
- CAN FD connection with switchable CAN termination
- 2 frequency outputs (Low-side switches, adjustable range)
- Analog input for voltage monitoring up to 30 V (12 bit)
- Aluminum casing with spring terminal connectors
- Extended operating temperature range from -40 to 85 °C
- Operating voltage 8 to 30 V

PCAN-MicroMod FD Analog 1:
- 8 analog inputs (16 bit, adjustable range)
- 4 analog inputs (12 bit, 0 - 10 V)
- 4 analog outputs (12 bit, adjustable range)
- 4 digital inputs (pull-up or pull-down)

PCAN-MicroMod FD Digital 1 / Digital 2:
- 8 digital inputs (pull-up or pull-down)
- 3 analog inputs (12 bit, 0 - 10 V)
- Digital 1: 8 digital outputs with Low-side switches
- Digital 2: 8 digital outputs with High-side switches

CANopen & CANopen FD Solutions

The PCAN-MicroMod FD DR CANopen Digital 1 is an I/O module for operation in CANopen (FD)® networks.

Main Features:
- CANopen® and CANopen FD® connection
  - Communication profiles according to CiA® 301 version 4.2.0 and CiA® 1301 version 1.0.0
  - Device profile according to CiA® 401 version 3.0.0
  - Certified CANopen® and CANopen FD® conformity
- 8 digital inputs, comply with the IEC 61131-2 standard
- 8 digital outputs with High-side switches
- Plastic casing (width: 22.5 mm) for mounting on a DIN rail

All PCAN-MicroMod FD products can alternatively be operated with CANopen® and CANopen FD® firmware from our partner Embedded Systems Academy.