September 2012

CANopen on track

Consist network applications and subsystems

Internationally standardized as part of the train communication network (TCN)

Applied in light rail vehicles including metros, trams, and commuter trains

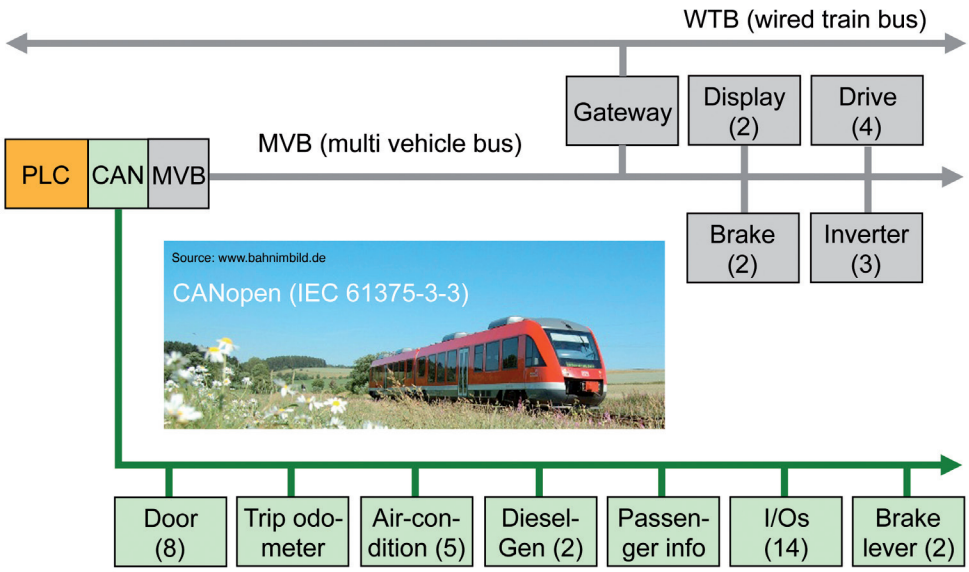
International standard for CANopen in rail vehicles

IEC 61375 standards

- **IEC 61375-1**
  Electronic railway equipment - Train communication network (TCN) - Part 1: General architecture
- **IEC 61375-2-1**
  Electronic railway equipment - Train communication network (TCN) - Part 2-1: Wire Train Bus (WTB)
- **IEC 61375-2-2**
  Electronic railway equipment - Train communication network (TCN) - Part 2-2: Wire Train Bus conformance testing
- **IEC 61375-3-1**
  Electronic railway equipment - Train communication network (TCN) - Part 3-1: Multifunction Vehicle Bus (MVB)
- **IEC 61375-3-2**
  Electronic railway equipment - Train communication network (TCN) - Part 3-2: MVB (Multifunction Vehicle Bus) conformance testing
- **IEC 61375-3-3**
  Electronic railway equipment - Train communication network (TCN) - Part 3-3: CANopen Consist Network (CCN)

In June 2012, the international electro technical commission (IEC) has enhanced the existing and well-established standard for train communication systems (TCN; IEC 61375), by the CANopen Consist Network. IEC 61375-3-3 specifies the data communication based on CANopen, inside a single rail vehicle or a consist in which several rail vehicles share the same vehicle bus. In general, the lower communication layers as well as the application layer are based on the well-proven standards for CAN (ISO 11898-1/-2) and CANopen (EN 50325-4). This allows on the one hand, profiting from the available CAN tools on the market. On the other hand it is possible to benefit from the broad range of available CANopen protocol stacks, CANopen configuration- and diagnostic tools as well as off-the-shelf devices (see CANopen product guide at www.cia-productguides.org). Well-defined communication interfaces will therefore simplify system design and maintenance.

In addition to enhanced lower layer definitions (such as e.g. CAN Identifier-format, type of connector, default bit rate, etc.) the new international standard IEC 61375-3-3 covers specifications for the network management within a CANopen-based Consist Network as well. A standardized gateway, that is defined in IEC 61375-3-3 as well, enables the full integration of CANopen-based consists in trains that follow the TCN architecture (defined by IEC 61375-1/-2).



TCN architecture with CANopen

The CANopen-based Consist Network is based on the robust and reliable ISO standard ISO 11898-2 for CAN physical layers. Additionally it specifies that the end devices have to be galvanically isolated from the communication network. Therefore within the end devices CAN transceiver (compliant to ISO 11898-2) and CAN controller (compliant to ISO 11898-1) have to be separated via an opto-coupler. The specified default bit rate is 125 kbit/s.

The end devices can be either connected to the CANopen-based Consist Network via D-sub9- or 5-pin M12 connectors. With regard to the data link layer, all definitions are based on the 11-bit CAN Identifier format. Nevertheless, CANopen-based Consist Networks utilizing the 29-bit Identifier format are not excluded.

IEC 61375-3-3: Interoperability based on CANopen

The CANopen-based Consist Network according to IEC 61375-3-3 assumes the CANopen application layer and communication profile. As CANopen is very flexible and scalable by means of a lot of optional features, the IEC 61375-3-3 provides some additional definitions to the CANopen standard EN 50325-4. These additional definitions provide the information, which optional features that are offered by the CANopen standard, are mandatory for end devices, participating in a CANopen-based Consist Network such as e.g. the Heartbeat protocol for error control or the Emergency protocol for diagnostic purposes.

In contrast to end devices that are participating in MVB-based Consist Networks, CANopen devices represent their application data directly in meaningful, dedicated objects in the manufacturer specific as well as in the standardized CANopen object dictionary index range. As application data has not been defined by IEC 61375 yet, it was not possible to define standardized CANopen object dictionary entries that provide predefined application data. Therefore, currently the application data has to be handled in the CANopen object dictionary index range for manufacturer specific profiles. Nevertheless, a representation principle was included, which introduces the reader on how to represent the application data within the CANopen object dictionary.

Bombardier Innovia 300 utilizing Selectron's redundant TCMS

As CANopen network management, from the point of view of a CANopen manager (CANopen device supporting the NMT master functionality) is not provided in EN 50325-4, the required definitions are provided in IEC 61375-3-3 as well. The CANopen manager issues not only the NMT protocol as defined in EN 50325-4 but boots the CANopen-based Consist Network according to a well defined boot-up procedure.

International CANopen related standards

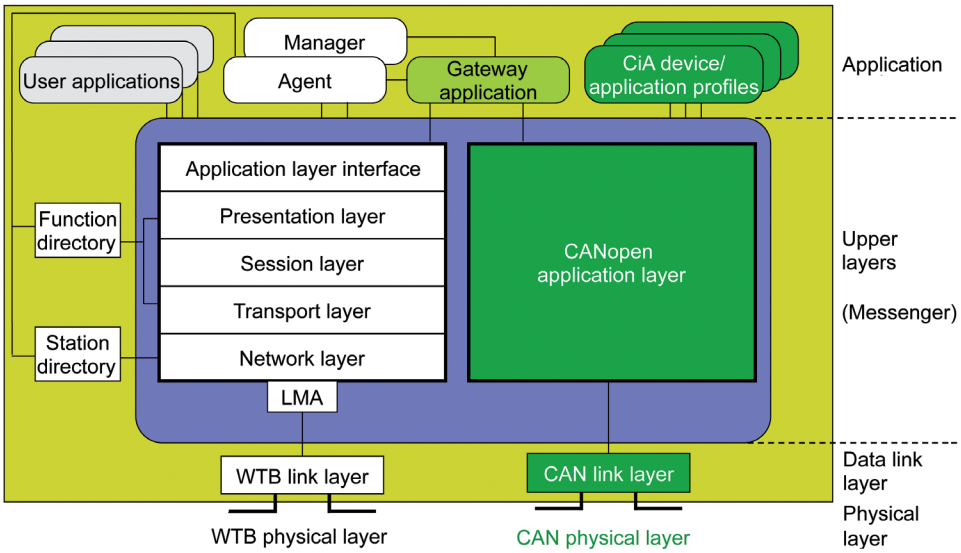
- **IEC 61375-3-3**
  Electronic Railway Equipment - Train Communication Network - Part 3-3: CCN - CANopen Consist Network
- **ISO 11898-1**
  Road vehicles – CAN – Part 1: Data link layer and physical signalling
- **ISO 11898-2**
  Road vehicles – CAN – Part 2: High-speed medium access unit
- **EN 50325-4**
  Industrial communications subsystem based on ISO 11898 (CAN) for controller-device interfaces – Part 4: CANopen
- **EN 50325-5**
  Industrial communications subsystem based on ISO 11898 (CAN) for controller-device interfaces – Part 5: Functional safety communication based on EN 50325-4

IEC 61375-3-3: Embedding CANopen in the TCN

CANopen in service in Flirt's operated by DB

Gateway devices between a CANopen-based Consist Network and a Train Backbone enable devices/applications within the TCN architecture, to access CANopen–based Consist Networks by means of network access services. These network access services are used on the Train Backbone interface of such a gateway device. The gateway device translates these network access services into the related CANopen services and issues the corresponding CANopen service on its CANopen interface and reports the response on the Train Backbone side as well. Therefore, it is possible to manufacture one type of standardized gateway devices. System designers can then rely on more reliable and safe products and in case of a damage, they can just exchange the faulty gateway device by a new one, without today's huge engineering effort for adopting manufacturer-specific gateway functions.

In addition to the definition of the network access services and their mapping to an generic ASCII protocol, the internal architecture of a gateway between the Train Backbone and a CANopen-based Consist network is defined. To enable the utilization of these network access services in TNM management messages, CANopen-specific management messages are considered. Therefore Train Network Management services can still assist commissioning, testing, operation and maintenance of a CANopen-based Consist Network.



Embedding CANopen in TCN architecture via standardized gateway device

As the complexity of a consist network may vary, the required capability of the gateway, which connects the consist network to the Train Backbone may vary as well. To represent this scalability in the standard, IEC 61375-3-3 defines 4 gateway classes. The scalable range starts with a simple gateway device, acting as simple NMT slave in the CANopen-based Consist Network. Such gateways are not able to communicate TCN management messages within a CANopen-based Consist Network but they can transfer the process data and can represent the process data at their CANopen interface. By means of supporting a higher gateway class the gateway increases its CANopen capabilities and may act finally as a CANopen manager within the CANopen Consist Network. In addition, all gateways that support a higher class than 0 may be capable to communication TNM management messages via the CANopen network.

CiA CANopen specifications

TCN-related CiA specifications based on UIC 556 define additional application data. The usage of IEC 61375-3-3 together with those CiA specifications increases interoperability.

- **CiA 421 series**
  Train vehicle control network
- **CiA 423 series**
  Diesel engine control
- **CiA 424 series**
  Door control
- **CiA 426 series**
  Exterior light control
- **CiA 430 series**
  Control of auxiliary equipment
- **CiA 433 series**
  Interior light control

IEC 61375-3-3: Benefits of CANopen consist network

The new part 3-3 of the international standard IEC 61375 for Train Communication Networks will provide CANopen the necessary acceptance in the application field of rail vehicles. Considering the existing CiA specifications for diesel engine control, door control, light control, etc., railway operators as well as manufacturers of rail vehicles can benefit of a high degree of standardization. They are no longer dependent of one single supplier. With regard to system integration and maintenance, they may choose from a broad range of available tools, offered by several manufacturers.

Suppliers of single devices or entire sub-systems are enabled to sell their identically configured products in several projects. Therefore, the diversity of variants as well as the effort of administration may be reduced. The independent user's and manufacturer's group CAN in Automation is glad to advise and actively support operators as well as manufacturers of rolling stock and equipment by the use of CANopen.

CANopen in service in SBB's „Dosto"

CANopen-based door control systems in trains in China

Nanjing Kangni Mechanical & Electrical Co., Ltd., is a Door System Manufacturer in Railway Transportation Industry who has the strongest R&D capability in China and the largest scale.

Kangni has been member of CiA since 2007, and now Kangni's door control system, based on an embedded CANopen network, has been used in many international projects.

The CANopen-based door control system is e.g. used in Bombardier's Innovia 300 MON Automated Monorail as well as in the Innovia 300 Metro. In addition it is used in the Citadis tram from Alstom as well as in the Nanjing Line 1 in rail vehicles from CSRN (China South Railway Nanjing Puzhen). But not only on board of rolling stocks CANopen is used in China. The platform screen door system in Nanjing is based on the CANopen control systems from Kangni as well.

Kangni uses CANopen in the door control systems to communicate configuration (e.g. type of closing, closing time, etc.) and diagnostic data. Of course, the process data such as door status information and commands are transferred in the CANopen network as well. With regard to door control system maintenance, Kangni implemented the ability to update the firmware of the devices in the door control system directly via the embedded CANopen network.

Bombardier Innovia 300 Monorail

Nanjing line 1 south extension Metro

Alstom Citadis tram

Citadis CANopen door control

Railway brake systems

Rapid Transit train in Zurich

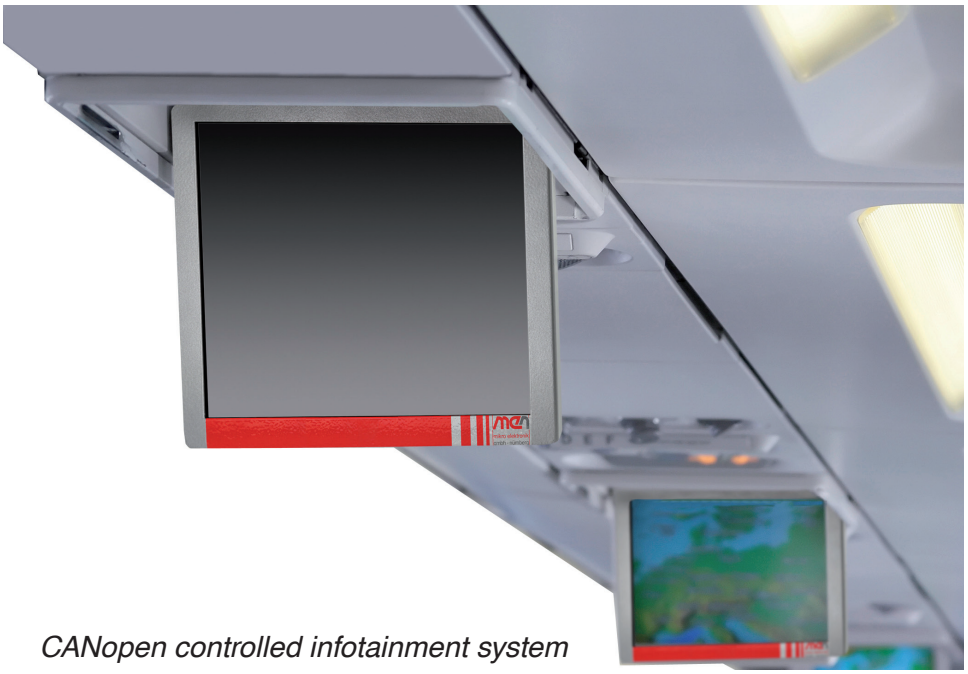
The Rapid Transit (S-Bahn) train Zurich is equipped with a CANopen brake system. The brake system consists of several pneumatic and electronic modules. The electronic modules communicate via the so-called ”brake-bus”, which is CAN-based and uses the manufacturer‘s proprietary higher-layer protocol. The brakes communicate with other systems in the vehicle via the “vehicle-bus”. The brake supports CANopen, EiA-485, MVB, and FIP. A German company equipped 120 units of the Rapid Transit train in Zurich, Switzerland with the brake system.

Passenger infotainment system

Features

- Orientation about stops
- Hints for changing trains
- Short-term changes of the route
- Delays
- Audio announcement of stops
- Controlling of video cameras in the stations
- Entertainment
- TV, video, DVD or radio programs
- -40 °C to +85 °C operating temperature

Due to infotainment systems, passengers no longer are at loss as to where exactly they are on the route, what the next stop may be or whether or not they will be able to catch the connecting train. Hints are given for changing trains and short term changes. Additionally general information such as news or wheather forecast is displayed. Audio data can be transmitted also. In this application audio announcements, passenger displays and the cameras in the stations are CANopen controlled.



CANopen controlled infotainment system

Protos light rail vehicle

Protos light rail vehicle by FTD

The Protos light rail vehicles by Fahrzeugtechnik Dessau (FTD) are electrically engineered by a member of CAN in Automation. Another CiA member supplies the door control units, which provide CANopen interfaces for integration into the vehicle network. The device controls the DC motor that moves the doors and the step treats by means of digital I/Os. The CANopen interface runs at 250 kbit/s. The modular Protos regional trains are powered by diesel or electro motors and achieve a maximum speed of 160 km/h.

CANopen controlled tramway in Italy

The 6000 series tram is the most modern vehicle operating in the city of Turin and Catania in Italy. This tram has sophisticated safety systems onboard, including an interactive intelligent diagnostic monitor installed in the driver's cabin. This monitor is a vital component of the tram and its malfunction causes the tram to become non-operative and requires the vehicle to be returned to the depot for maintenance. This monitor is not just a display as the name suggests, but an embedded computer with display capability that works as an HMI for the driver.

6000 series tram operating in Turin

The emVIEW installed in driver's cabin

Severe design issues afflicted the original monitor developed by the tram-manufacture. There were problems related to the environmental conditions with special regard to the extended temperature range and humidity. Turin is a city with cold winters and hot summers while Catania is very hot in summertime.

LVD Systems the local representative of Janz Tec in Italy proposed in fall 2008 to the local transportation company (GTT) a solution based on a Janz Tec emVIEW series monitor. The 8-inch PanelPC based on ARM architecture running embedded Linux was the winning choice.

In addition to the Turin City public transport company (GTT), the Catania public transport company bought units to replace malfunctioning Diagnostic Monitors. The popular CAN bus interface has been selected to connect all the devices for the command- and control system of the Torino city train.

The software implementation is an adapted protocol compatible with the standardized CANopen protocol. This allows the use of standard COTS CANopen devices as well as special customized devices for the specific needs of the city train. In order to reach that result a special SDO has been implemented with COB-IDs compatible to standard CANopen. The 11 bit base frame format is used to communicate among the devices. The supervisor / master of the system uses a Janz Tec CAN interface (VMOD-FCAN) to interface all the network participants. The protocol that is used is primary based on the communication services: write PDO and read PDO.

The operator is enabled to read the current alarm status of each device of the system.

CANopen in Chinese rail vehicles

CSR QSY's PN Locomotive that has been put in service by Australia Pacific National Locomotive. Redundant TCMS is based on a CANopen vehicle bus

Advanced Rapid Transit Beijing China

Metro Line 1 South Extension Nanjing China

Metro Line 4 II MTR Shenzhen China

CSR Nanjing Puzhen Rolling Stock and CNR CRC use within their rail vehicles the CANopen-based TCMS (train control and monitoring system) provided by the Swiss company Selectron. The TCMS uses redundant PLCs, programmable in IEC 61131-3 languages. The "strong" (default) vehicle control unit and the "weak" (warm stand-by) controller crosscheck their "Heartbeats". The Heartbeat is a special CANopen service to indicate the device status and its availability.

CSR is using CANopen since 2006 in several Chinese metro trains. In some projects a CAN-Powerline inter-coach network is installed, e.g. in the six-coach trains in Nanjing. CNR CRC has equipped the Changchun rail vehicles with a CANopen network using repeaters and bridges. Some sub-systems such as HVAC and door controllers are connected to CANopen by means of EIA 485 gateways.

The TCMS hardware is as the other devices by Selectron compliant with the EN 50155 standard. Besides PLCs and I/O modules, the company provides CANopen gateways for CAN-Powerline, MVB, and EIA 485. These products have been successfully installed in several trains and locomotives. Largest customer is Stadler (Switzerland) using the CANopen products in its Flirt train, for example. In several retrofitting projects, the CANopen devices have been installed as well.

In order to simplify system integration and maintenance the TCMS manufacturer selectron provides its Concerto series of tools, including a configuration and maintenance software. There is also data-logger hardware available. These products complete the tool portfolio such as the CAP1131, the TOP1131, and the MaestroPro development software.

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