June 2021

CAN Newsletter

Hardware + Software + Tools + Engineering

CANopen gateway for truck bodybuilders

Robotics, analysis, and handling systems

CANopen FD devices identification via LSS

CANopen FD use cases

Company portrait: Bürkert & CANopen

CANopen (FD)

www.can-newsletter.org

Measuring Unit with CAN FD Interface

MU-Thermocouple1 CAN FD

The MU-Thermocouple1 CAN FD from PEAK-System allows the measurement of 8 temperatures via thermocouples of the types K, J, or T depending on the product version. The measurement data is transmitted via a CAN interface that supports the modern standard CAN FD in addition to CAN 2.0.

Data processing, message transmission, and LED indication are set up with a free Windows software. The configuration created on the computer is transferred via CAN to the device which then runs as an independent CAN node. Multiple devices can be configured independently on a CAN bus.

Specifications

- 8 Mini sockets for thermocouple types J, K, or T
- 4 galvanically isolated measuring modules, each with 2 thermocouple sockets of the same type
- Measuring ranges:
  - J: -210 to +1121 °C (-346 to 2050 °F)
  - K: -200 to +1370 °C (-328 to 2498 °F)
  - T: -200 to +400 °C (-328 to 752 °F)
- Measurement accuracy: 0.2 % or 1 K
- Accuracy of the reference temperature sensors at +25 °C ambient temperature: typically ±0.5 K, maximum ±1.0 K
- Maximum resolution of temperature data: 1/16 °C
- High-speed CAN connection (ISO 11898-2) for data transfer and configuring
  - Complies with CAN specifications 2.0 A/B and FD
  - CAN FD bit rates for the data field (64 bytes max.) from 25 kbit/s up to 10 Mbit/s
  - CAN bit rates from 25 kbit/s up to 1 Mbit/s
  - NXP TJA1044GT CAN transceiver
  - Galvanic isolation up to 500 V
- LEDs for measurement channels and power supply
- Configuration with a Windows software via CAN (requires a PEAK CAN interface)
- Voltage supply from 8 to 30 V
- Extended operating temperature range from -40 to 85 °C (-40 to 185 °F)

Scope of Supply

- MU-Thermocouple1 CAN FD in aluminum casing
- Mating connector for voltage supply
- Configuration software for Windows
- Manual in PDF format

www.peak-system.com

Take a look at our website for the international sales partners. Scan the QR code on the left to open that page.

PEAK-System Technik GmbH

Otto-Roehm-Str. 69, 64293 Darmstadt, Germany
Phone: +49 6151 8173-20 - Fax: +49 6151 8173-29
E-mail: info@peak-system.com

CANopen

CANopen gateway for truck bodybuilders 4

Robotics, analysis, and handling systems with CANopen 8

Company portrait: Bürkert & CANopen 12

CANopen FD

CANopen FD devices identification via LSS 16

CANopen FD use cases 20

Engineering

CAN XL documents under development 18

CAN decoder warns for malicious attacks 23

Comparing CAN, CAN FD, and Ethernet 26

Inclusive language

Language is one of the most powerful tools we have as human beings, and it is important to make sure we are using it to create an inclusive environment where everyone feels welcome. Therefore, we need to ensure that language evolves over the years so as to not exclude people. Inclusive language avoids biases, slang, or expressions that discriminate against groups of people based on race, gender, or socioeconomic status. CiA is committed to use inclusive language. This is also demanded especially from multi-cultural nations such as the United States of America and the European Community. Many U.S. enterprises have started already to implement the usage of inclusive language in technical documentation including handbooks, data sheets, and product descriptions. There are general guidelines for inclusive language by the Linguistic Society of America (LSA). Also, ISO provides inclusive language recommendations in its ISO House Style editing rules. Non-inclusive terms are used for many years. These are well known – some of them since generations of engineers. They are used in handbooks, data sheets, specifications, standards, patents, whitepapers, presentation handouts, conference proceedings, etc. CiA is committed to replace them by inclusive language terms in all of its provided hardcopies and online media including contributions in social media.

Imprint

Publisher
CAN in Automation GmbH
Kontumazgarten 3
DE-90429 Nuremberg

publications@can-cia.org
www.can-cia.org

Tel.: +49-911-928819-0
Fax: +49-911-928819-79

CEO
Reiner Zitzmann
AG Nürnberg 24338

Downloads March issue:
(retrieved May 25, 2021)
4345 full magazine

Editors
Olga Fischer (of)
Cindy Weissmueller (cw)
Holger Zeltwanger (hz)
(responsible according to the press law)
pr@can-cia.org

Layout
Nickel Plankermann

Media consultants
Rosanna Rybin
Tobias Kammerer
Birgit Ruedel (responsible according to the press law)
publications@can-cia.org

Table of contents

CANopen gateway for truck bodybuilders

Ulrich Hiermann is the chairperson of the CiA SIG (special interest group) truck gateway, which has been reawaked beginning of this year. This group maintains the CiA 413 CANopen truck gateway series specifying the interface to CANopen-based bodybuilder networks.

Figure 1: Ulrich Hiermann (Source: Iveco)

The higher flexibility and configurability of CANopen compared with J1939 fits to the highly-fragmented body application market. Hiermann is responsible for the development of Iveco's gateway between the in-vehicle networks and the body applications. He is working with Iveco for more than 30 years.

CAN Newsletter: Since when does Iveco provide a CANopen interface for bodybuilders?

Hiermann: For heavy-duty trucks, Iveco supports CANopen bodybuilder (BB) gateways since 2009. One year later, we equipped the medium-range of our trucks with this gateway. In 2012, the light-range trucks followed.

CAN Newsletter: Which features does this interface support?

Hiermann: Iveco offers a modular BB interface. The Highline version complies to the CiA 413 series of CANopen truck gateway specifications. The Heavy MY2019 version of the CiA 413 gateway supports 462 process data to be transmitted and 91 process data to be received from the body application. This variety of available process data allows developing and integrating seamless advanced BB functions. These process data (some call this signals) are mapped to PDO messages by means of configuration.

CAN Newsletter: What is the feedback from customers?

Hiermann: So far, the customers are satisfied. The feedback is positive confirmed by continuous increasing sales for the CANopen option of our BB gateway. According to our experience, CANopen is suitable for any kind of BB applications. It allows both highly-customized solutions as well as J1939-like solutions. The main benefit is that the CANopen communication can be tailored offering application-specific setups also for low-performance BB controllers. These simple ECUs (electronic control unit) can often just manage a reduced CAN interrupt load.

Customers being familiar with CANopen are profiting on a fully autonomous truck gateway mapping possibility gaining highest flexibility. This protects the know-how of our customers.

CAN Newsletter: What has been improved in the last years?

Hiermann: Additional process data – often named signals – are continuously implemented in the CANopen gateway depending on truck evolution and customer needs. We also add transparency between Truck and BB equipment, keeping our customers informed, whether in-vehicle networks operate without problems. This is especially necessary, when the body application accesses the in-vehicle networks via the CANopen gateway. The embedded firewall in the gateway unit accepts or denies certain functional requests from the CANopen-based body network. To satisfy the various market requirements this firewall can be customized upon bodybuilder specific requests.
Iveco customizes the CANopen gateway, if demanded. For example, the reaction of the vehicle can be tailored, when the Heartbeat message of the body controller is missing. In such cases, the CANopen gateway can transit automatically into NMT stopped state.

Figure 2: Iveco S-WAY truck with HS refuse body (Source: Iveco)

CAN FD + LIN TOOL

FOR INDUSTRIAL ENVIRONMENTS

ValueCAN 4 INDUSTRIAL

Independently isolated CAN FD and LIN for automation and industrial environment.

- 2 Independently galvanically isolated CAN FD channel backward compatible with CAN 2.0
- 1 Independently galvanically isolated LIN channel also configurable for K-Line
- Configure or Monitor using USB or Ethernet connection using a standard shielded RJ45 socket
- Input power 9VDC-42VDC; the unit consumes 200mA if powered at 12VDC, or 100mA if powered at 24VDC
- USB Type-C connection for RAD-IO2 Isolated Analog, Digital or Temperature Interfaces
- Snaps on to DIN rail for easy installation and an organized way to handle complicated wiring circuits

Find out more: www.intrepidcs.com/vcan4ind

INTREPID

CONTROL SYSTEMS

www.intrepidcs.com

+49 (0)721 1803083 -1 icsgermany@intrepidcs.com

USA Germany UK Japan Korea China India Australia

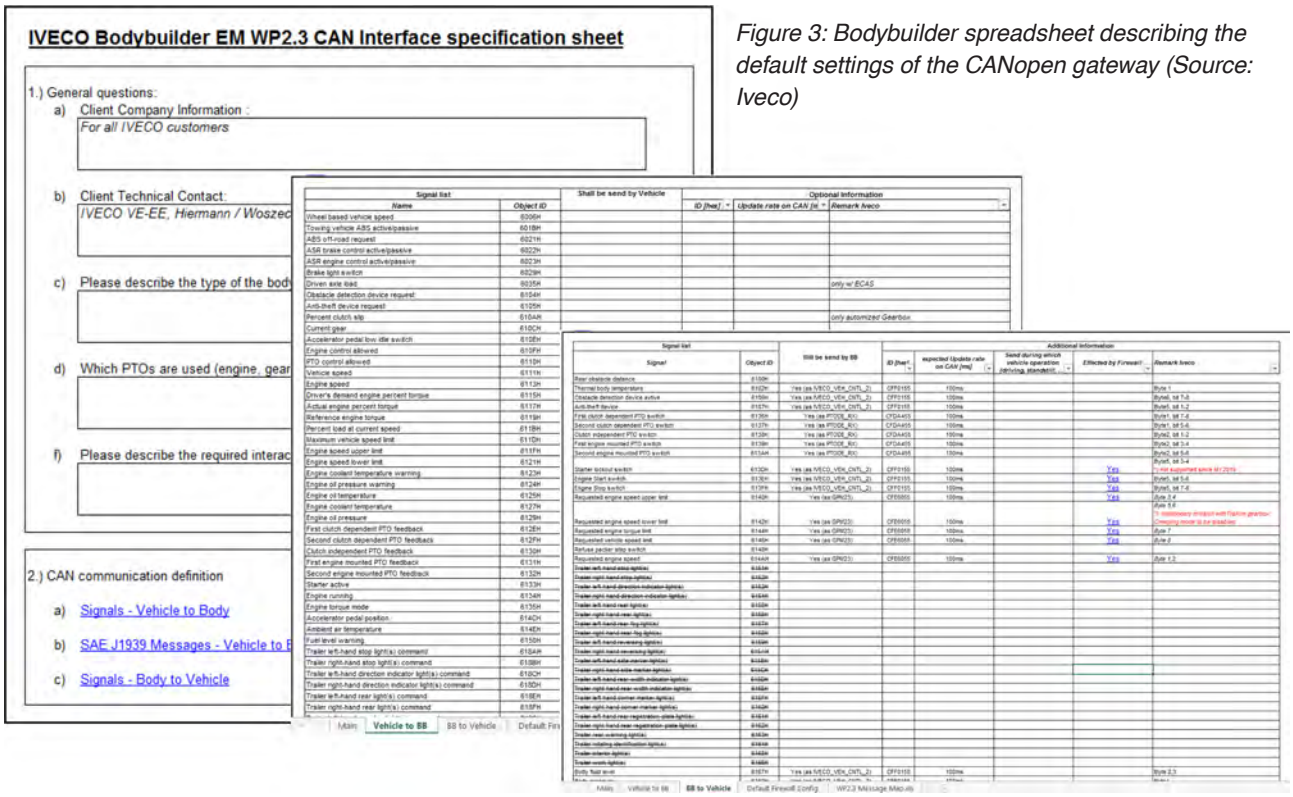


Figure 3: Bodybuilder spreadsheet describing the default settings of the CANopen gateway (Source: Iveco)

Over the years, an easy CANopen gateway configuration process was established. This includes guiding and supporting bodybuilders step by step. The process starts already, when a truck is ordered and the desired truck options are to be selected. Iveco offers a portfolio of branch specific ready-to-use CANopen configurations. For selecting suitable CANopen configuration(s) the customers simply select the needed process data to be transmitted and to be received by the CANopen gateway and receive a list of matching CANopen configuration(s). This simplifies and speeds up the interface development.

CAN Newsletter: What are the next developments?

Hiermann: We plan to identify future needs in close cooperation with bodybuilder associations. This includes for example extended fleet management and telematics features for BB equipment and devices as discussed in DIN. Iveco is committed to support actively CiA specifications to extend the CiA 413 series in this direction specifying the mapping of DIN 4630 parameters to CANopen. Other functional extensions include alternative traction such as compressed natural gas or liquefied natural gas as well as zero emission vehicles. When the CiA 413 series is updated, Iveco will consider them on new developments.

CAN Newsletter: Could you please share some success stories about the CANopen interface?

Hiermann: There are many bodybuilders using our CANopen gateway. It us used in plenty applications, like concrete mixers, liquid-transporting trucks, and bodies using hydrostatic drives. For various BB applications the communication is reduced onto essential parameters, aiming to reduce the CAN interrupt load on the body controller. For example, Europe Zoeller connects its refuse collecting bodies compliant with the CiA 422 application profile via our CANopen network to the in-vehicle networks. There the bodybuilder configures at startup – if needed – the Iveco CANopen gateway. They do not use Iveco RCV CANopen configuration, instead they select only signals needed to manage their features. Adding features – also on vehicles already sold – can be managed easily without any Iveco involvement.
Another success story for proofing our gateway setup process is the Pumpboss project for firefighting trucks in Australia. The challenge was to physically built-up a vehicle in Australia, integrating a US bodybuilder equipment and managing development from Europe.

CAN Newsletter: Does Iveco consider to support other bodybuilder standards such as DIN 4630 and DIN 14704?

Figure 4: Iveco Eurocargo for municipal applications with different bodies (Source: Iveco)

Figure 5: Iveco Daily with Kuepper Weisser winter equipment and Unsinn roll on/off system (Source: Iveco)

Hiermann: Iveco appreciates to extend the CiA 413 series, allowing the support of the DIN 4630 and the DIN 14704 parameters. We are always open for bodybuilder requests and to standardize them.

CAN Newsletter: What is the future strategy regarding the bodybuilder interface?

Hiermann: Safety and cybersecurity are mandated by regulations. We are ready to adapt them. Cross system safety – in other words: safety between vehicle and bodybuilder equipment – needs be investigated with bodybuilder associations and standardization bodies. Iveco is committed to support such approaches, which can be referenced by national and international legislation authorities. ◀

Interviewer

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

(Source: Maxon)

Robotics, analysis, and handling systems with CANopen

Robotics, analysis, and handling systems require a compact integration of a large number of energy-efficient drives, combined with dynamic controllers and a serial network system. Maxon provides solutions with CANopen.

In particular, surgical robots, analysis devices in medical and laboratory technology, and multileaf collimators in radiation technology rely on miniaturized drive systems which can be installed densely packed due to their efficiency. In addition to motors, the ideal "drive package" also includes motor controllers that can be integrated directly in the device close to the motors and sensors. The requirement are compact multi-axis system concepts. An operation robot is a typical application with multi-axis systems (see photo above).

The most important features of the motor controllers are energy efficiency and power density for the space-saving integration of all components. The motor controller should be able to provide its rated power without the need for any additional cooling measures like heat sinks or fans which would increase the overall dimensions strongly again. Equally important are connections for various sensors and actuators as well as a fast network interface. The Epos Micro modules offer a standardized range of functions, control algorithms, a compact power stage, and a CANopen interface – while being similar in size to a postage stamp (from 32 mm x 22 mm). Device manufacturers can integrate the plug-in modules in their own electronics in the required number of axes. This makes cost-optimized multi-axis systems with compact dimensions possible. The Epos4 Micro 24/5 digital positioning controller for example, provides a CANopen (responder) interface. It complies with the CANopen application layer and communication profile CiA 301, CiA 305 CANopen layer setting services (LSS) and protocols, as well as the CiA 402 CANopen device profile for drives and motion control.

CANopen: The backbone of the overall system

Each drive unit exchanges command and status data with the commander controller (e.g. programmable logic controller or Maxon Mastermacs) by its network interface in a ▷

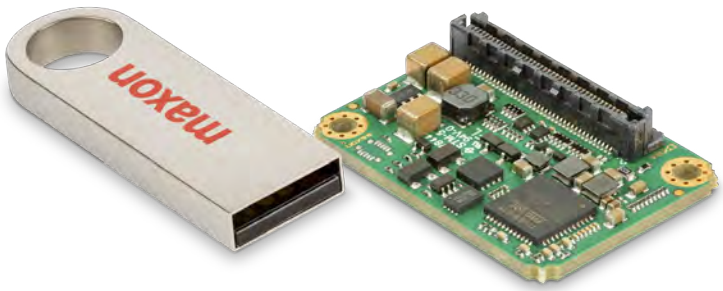


Figure 1: The size of the Epos4 Micro compared with an USB stick (Source: Maxon)

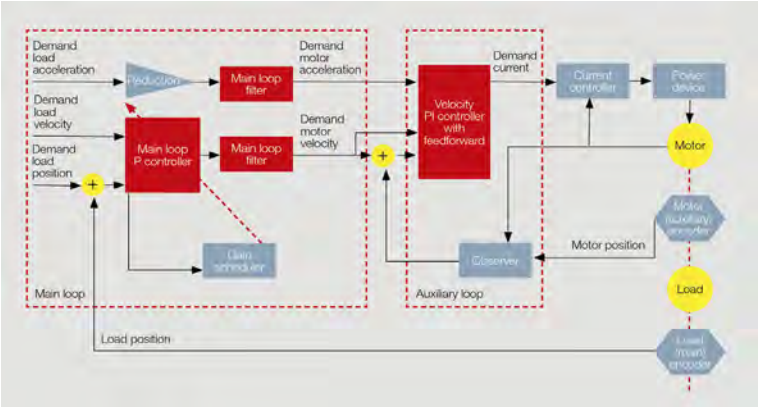


Figure 2: Detailed view of all components of Epos4 dual-loop control (Source: Maxon)

fast cycle rate. One commonly used serial network system is CANopen. It has been industry-proven by an endless number of medical and industrial applications. It is the backbone of any reliable real-time data exchange of multi-axis applications, e.g. drives or robotic joints which demand for some coordinated or synchronized motion.

Integration based on CiA 402

Any data exchange and commanding of the Epos4 Micro complies with the CiA 402 protocol. The standardized operating modes PPM – profile position mode, PVM – profile velocity mode, HM – homing mode, CSP – cyclic synchronous position, CSV – cyclic synchronous velocity, and CST – cyclic synchronous torque, are supported. As a standardized motion control responder, Epos4 Micro (like all Epos4 product types) can be integrated by the system manager tools and motion libraries of different PLC (programmable logic controller) manufacturers. Applications commanded by a PC or Raspberry Pi and Maxon's Epos Command Library are possible too.

Epos4 Micro supports brushed and brushless DC motors with hall sensors, digital

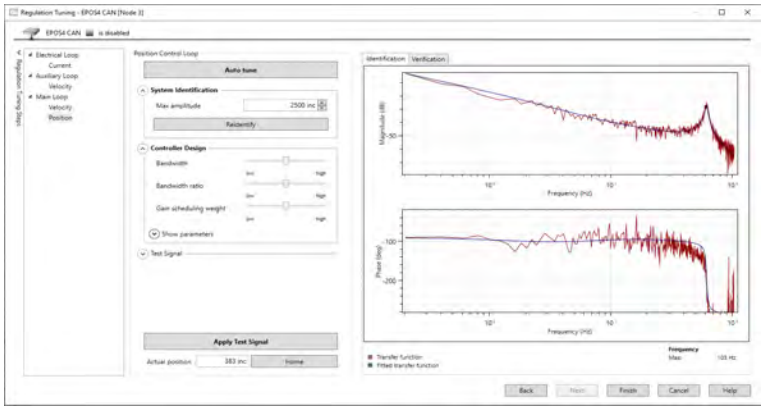


Figure 3: Epos Studio: dual-loop regulation tuning (Source: Maxon)

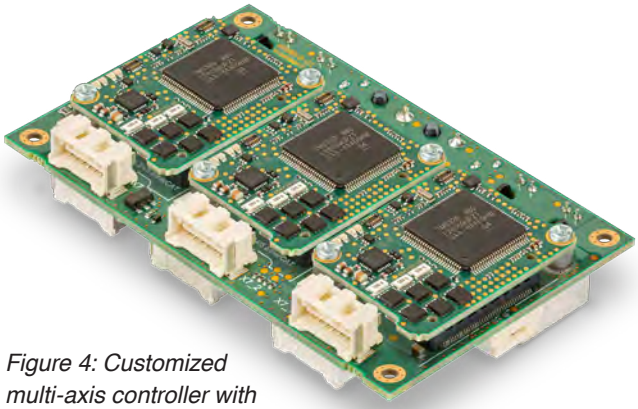


Figure 4: Customized multi-axis controller with three Epos4 Micro (Source: Maxon)

incremental encoders, and SSI absolute encoders. A total of five digital inputs, three digital outputs, two analog inputs (+/-10 V), and one analog output (+/-4V) allow the connection and processing of add-on actuators and sensors. The product series offers a power density of over 50 W peak power per cm^2 mounting surface without additional cooling at an environmental temperature of -30 °C to +45 °C. This means a continuous output power of 120 W and peak of 360 W for 10 seconds based on a footprint for controller and power stage of only 32 mm x 22 mm and 7 mm thickness.

With its 25-kHz current control cycle and 2,5 kHz speed/position control cycle, the product series has identical cycle rates like all other Epos4 product types. Modern controller concepts such as field-oriented control (FOC), feed forward, and observer control also mean that the Epos4 Micro can provide a maximum motor performance and movement precision.

Dual-loop control included

Quite often mechanics is not “perfect” and there is some backlash (by gears) or elasticity (by belts) present. The position accuracy of the moved load is the one that finally counts in practice for the user of a machine or robot. The Epos4 offers dual-loop control for such mechanical systems. Dual-loop control is based on an encoder mounted on the motor shaft and another additional encoder mounted on the output shaft. The motor encoder is in use for sinusoidal commutation (so-called FOC) and velocity control. The encoder mounted on the output shaft is the feedback device of the position control loop. This so-called dual-loop control and all encoder data is fully processed by the Epos4 and ensures smooth highly dynamic motion and precise positioning of the load. Dual-loop control is integrated in the Epos4 Micro with the same functionality and performance like for all other Epos4 product types. The compact size of the Epos4 Micro means no restriction at all.

One challenging point of most motor controllers and especially dual-loop control is often initial commissioning demanding for the configuration of a lot of control parameters of complex cascaded modern control loop algorithms. A wrong manual configuration of control settings often results in disappointing control performance even in case of a highly sophisticated motor controller. Maxon offers a comprehensive set of software tools by the Epos Studio PC software which can be downloaded free of charge. The technical data of the motor and sensors in use are configured by Epos Studio’s “startup” wizard based on the component’s data sheets. Epos Studio’s “regulation tuning” reduces perfect tuning results to the press of a button even in case of dual-loop control by a next step. An optimized motion control configuration can be realized by tools like Epos Studio.

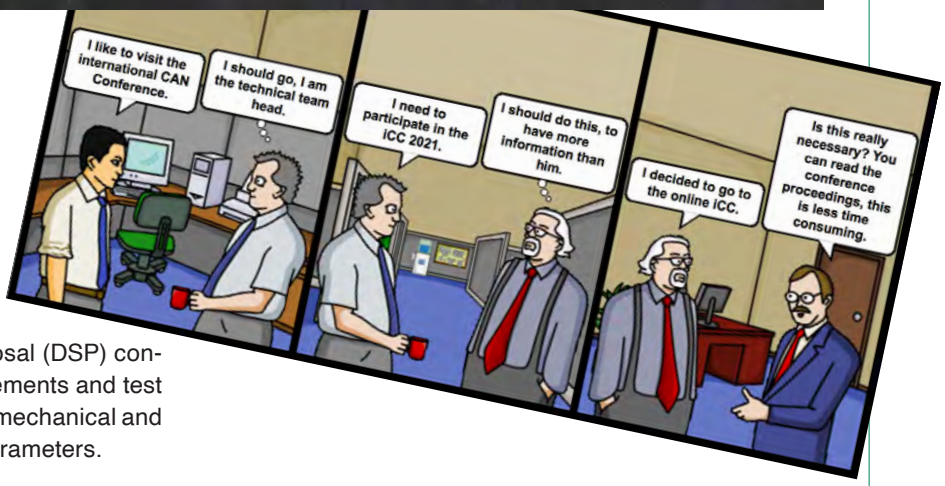
The Epos4 is the lowest-level information supplier in the IIoT (Industrial Internet of Things) environment of a machine or drive train. Motor current and torque, speed, position, error states, temperature, and load values of the controller and motor, as well as sensor and actuator states can be accessed or periodically transmitted by its network interfaces. ◀

Author

Jürgen Wagenbach
Maxon Group Motion Control
support@maxongroup.com
www.maxongroup.com

Facts & Figures

CiA 110



This document specifies Classical CAN/CAN FD common mode chokes. The CiA 110 draft specification proposal (DSP) contains requirements and test methods of mechanical and electrical parameters.

The international CAN Conference (iCC) is scheduled for four half-days in June (14th to 17th). Registration is still open. The conference introduces the CAN XL lower layers and the CAN FD Light protocol. There are also sessions on CANopen FD, CANopen testing, CAN FD physical layer, CAN security, and CAN XL higher layers. The keynote speaker is Carsten Schanze from Volkswagen talking about the future of CAN from prospective of an OEM (original equipment manufacturer).

SAE J1939-22 and CiA 602-2

SAE has specified the mapping of the J1939 application layer to the CAN FD data link layer. The recently released J1939-22 document introduces a new transport protocol as well as the Multi-PDU concept originally specified in CiA 602-2. The CiA document has been withdrawn with the publication of J1939-22 to avoid double-specifications.

CiA 461 series

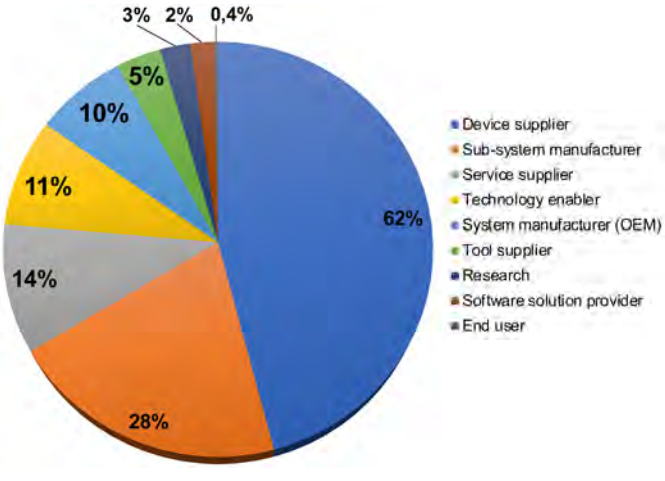
CiA has released updated profile specifications for CANopen load cells, scales, and HMI (human machine interface) devices. The four documents of the CiA 461 series are published as draft specification proposals (DSP). They introduce functional safety capability compliant with CANopen Safety (EN 50325-5).

691 members

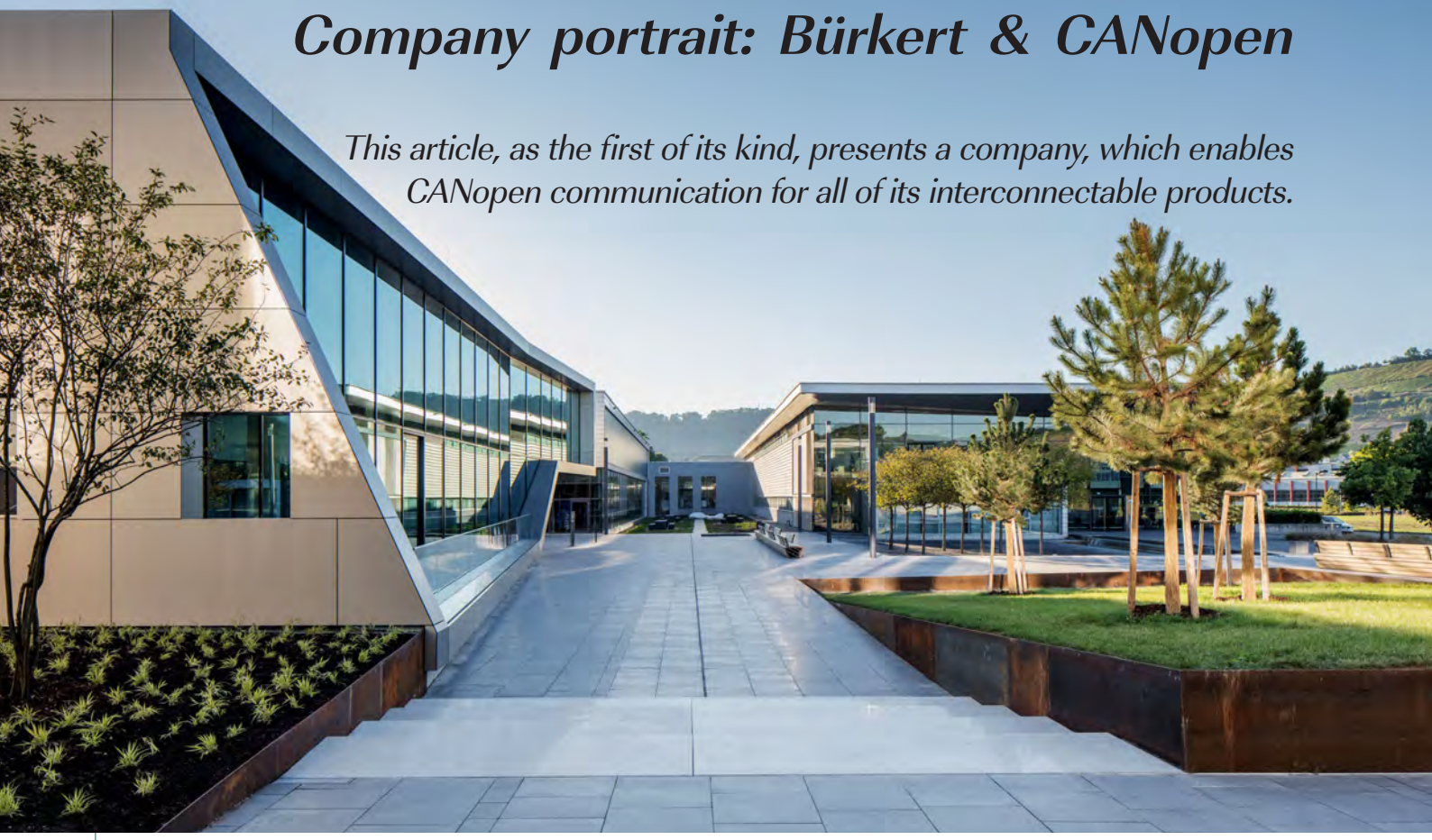
In March, the nonprofit CiA association counted 691 members. Most of them are located in German-speaking countries (51 %) followed by North European countries (10 %) and the two North American nations (9 %). About 8 % are coming from Italy and 4 % are headquartered in China. The remaining 18 % are mainly spread on the northern hemisphere.

About 62 % are device suppliers

The figure shows, which products and services the 691 CiA members provide. Multiple answers were possible.



Company portrait: Bürkert & CANopen



This article, as the first of its kind, presents a company, which enables CANopen communication for all of its interconnectable products.

Founded in 1946 as a family business and headquartered in Ingelfingen (Germany), Bürkert employs more than 2500 persons in 36 countries. Round about 1600 employees are working in Germany. The five system houses, providing complete system solutions and the related services, are located in Germany (3), USA (1), and China (1). The company's products are manufactured at five sites in Germany and France. Ca. 8,4 % of the stuff are working in the area of R&D (research and development). The most part of the manufactured products (more than 70 %) is sold outside of Germany.

The company offers products and complete customized solutions for fluid control systems. Such systems include devices for process automation, analysis, flow, pressure, level, and temperature control, as well as for dosing, and filtration. Networking of the devices via CANopen (and other networks) enables control, monitoring, analyzation, and maintenance of the processes. Using the EDIP (efficient device integration platform) devices can be networked and operated with the Bürkert Communicator software.

Figure 1: Water analysis systems, medical and laboratory equipment, food and beverage, are only few application area examples (Source: Bürkert)

The company's portfolio includes solutions for water and gas industries, as well as for industries with high hygienic requirements. Systems handling the flow in microliters (e.g. dental chair control unit) are offered as well. Water analysis systems, medical and laboratory equipment, food and beverage, are only few application area examples.

Philosophy

Bürkert acts according to the company's brand values: courage, experience, and closeness. The experienced experts are perpetually sharing and building their knowledge base internally. Closeness is more than just a personal cooperation while supplying a product and customer services. Closeness creates trust and builds partnerships. Courage can best emerge with the backing of solid experience and trusted individuals. The company therefore places strong emphasis on building long-term partnerships, both internally with colleagues and externally with customers. This is about looking to the future, anticipating customer needs, seeing the possibilities, and challenging the status quo.

Q & A with the company's experts

CAN Newsletter: Why do you rely on CANopen?

Ralf Schmötzer: The CAN bus is very robust and already integrated in the most micro-controllers. In combination with the CANopen higher-layer protocol, we have a real-time capable

Ralf Schmötzer (Expert Industrial Communication R&D, Ingelfingen)


KVASER
Rugged,
Powerful,
Intuitive.
CAN FD to USB.
Introducing
THE KVASER U100
LEARN MORE
TX
RX
01000177
KVASER

communication network that meets all the company's requirements. These properties offer ideal conditions for connecting devices to each other and to the control systems. CANopen has established itself as the standard interface for our devices. All interconnectable Bürkert devices are equipped with a CANopen interface, which enables us to configure the devices in production but also in the field by using our configuration tool. With the Communicator tool, a central access to all device data and parameters is made possible. In addition, the values can be brought into a relation to each other with various visualization options such as a graph.

CAN Newsletter: How do customers network their CANopen devices?

Ralf Schmötzer: Many customers integrate the devices directly into their CANopen-capable PLCs (programmable logic controllers) or expansion modules. But there is also a large group of customers who rely on protocols such as Profinet, EthernetIP, ModbusTCP, CC-Link, Profibus, or Ethercat. Here we also have a solution named EDIP (efficient device integration platform). With this system, the customer forms a CANopen sub-network and only communicates the parameters and process data relevant to their application via a CANopen-to-Ethernet gateway to the higher-level PLC (programmable logic controller). The whole chain can be configured with the Communicator tool without having in-depth technical knowledge of the respective protocols. The result is a configured CANopen network and a generated device description file for the target system. In the Profinet example, this would be a GSDML file that represents all CANopen objects with the configured object names.
This procedure saves time when engineering the PLC, as all physical functions are represented by a device with application-specific names. Furthermore, the EDIP platform offers the customer the option for installation of additional functions such as displays or OPCUA (open platform communications unified architecture) communication in parallel. The modules are optionally available for the control cabinet or as IP67-protected versions for the field installation. Additional use of I/O modules enables collection of non-digital signals in the field and transmission of them to the PLC via the gateway.

CAN Newsletter: How can the use of the system solutions shorten machine downtimes?

Ralf Schmötzer: Every customer system needs maintenance at certain intervals. The trend in today's digitization progress is the predictive maintenance. Bürkert also takes up this idea and delivers CANopen-based products with the EDIP platform, which provide numerous analysis and diagnostic data. The diagnostic data can usually be transferred via SDOs (service data objects).
In addition to the data availability, machine downtime plays a decisive role in customer systems, for example in case of device defects. We offer numerous options for device replacement without having to reconfigure the network. These options include, for example, a SIM card, a configuration client/provider function, as well as backup and restore functions.

CAN Newsletter: Are you planning to use CANopen FD?

Ralf Schmötzer: We are actively following this topic and also the availability of the chips on the market. At the moment we have not yet reached the limit of the CANopen performance with our devices. This means that we do not feel any pressure to take the next step towards CANopen FD. However, since the implementation of CANopen FD is very promising, we are always looking into the option of equipping the next generation of devices with CAN-FD-capable hardware.

CAN Newsletter: Which and how many departments are working on CANopen developments?

Ralf Schmötzer: Since CANopen is built into all of our intelligent devices, many of our developers are also in contact with the CANopen technology. This also applies to colleagues outside of development, colleagues from E&C (engineering and consulting), and the system houses that offer customized complete systems.

CAN Newsletter: Which role does CANopen play in your product strategy?

Nandini Mungee
Product Manager Industrial Communication, Ingelfingen

Nandini Mungee: CANopen has proven to be a reliable and robust technology in various industrial environments for many of our customers. Our goal with the device platform EDIP has been to strike a balance between complexity and acceptance. We have managed to implement CANopen in a way that, the user does not need any in-depth knowledge of the protocol to be able to work with our devices. In short, it plays a very vital role and holds everything together!

CAN Newsletter: How does Bürkert position CANopen alongside growing number of IoT solutions and Ethernet-based technologies?

Nandini Mungee: Over the last decade, we have seen different kinds of automation concepts at the customer sites. As a device manufacturer, we need to be flexible and place our customer's needs before anything else. With the EDIP platform, we are able to provide a solution for every kind of automation concept. Often, we offer solutions with CANopen as a sub-network with another Ethernet-based protocol on top. I do not think "one-size-for-all" kind of a solution fits in such diverse industrial scenarios. We want to make the best out of the diversity.

CAN Newsletter: Which advantages offers the CANopen platform EDIP for digitalization of customer systems?

Alexej Iwaschkin System Engineering, System House Criesbach

Alexej Iwaschkin: The aim of Industry 4.0 and the associated digitalization is to optimize processes. This also applies to development of individual solutions and products for various process technology areas. As a rule for fluid process technology, liquids and gases need to be measured, mixed, and the processes have to be controlled. New ideas are often made possible through cross-sector thinking and the networking or digitalization of development and manufacturing processes. For this reason, the CANopen platform EDIP enables connection with customer applications and digitalization of these applications with various system solutions. The idea of plug-and-play or plug-and-produce is always in the foreground. Thus, numerous company-patented functions are available, especially with the Communicator software.

The Communicator enables installation of a customer system, which usually includes the following steps:

- Parameterization of the connected CANopen devices: The automatic device addressing enables the connection to a CANopen network at the same time. Manual addressing is not required. The clear network participant naming in connection with the Namur LED makes it easier to find devices in the customer application during the subsequent maintenance work.
- Gateway configuration and mapping: The gateway configuration can be adapted automatically or with the help of product catalogs to customer requirements or to the customer application without additional effort. This means that the PLC programming or the interpretation of the configured values for the PLC programmer becomes easier. Also, the mapping of the configured values in the gateway is no longer in the responsibility of the customer.

To sum up: The CANopen platform offers an advantage for the system development. System solutions with different kind of product types can be flexibly set up, simulated, configured, and thus adapted to customer requirements. Furthermore, only one tool has to be used for parameterization, configuration, and analysis. This avoids additional license costs and trainings, also for our customers. ◀

Olga Fischer (CAN Newsletter)

info@burkert.com
www.burkert.com

Products for process automation

The ME43 is a gateway and control unit consisting of a fieldbus coupler and based on the EDIP platform. It transmits the data of the networked CANopen devices (valves, sensors, mass flow controllers, displays, etc.) to Ethernet-based networks (e.g. EthernetIP, Profinet, and Ethercat). Using a graphical programming, CANopen sub-systems can be automated according to the customer's requirements, for example, controlled mixing of gases, error monitoring via limit value switches, and time switches.

Figure 2: CANopen-to-Ethernet gateways ME43 and ME63 (Source: Bürkert)

The ME63 CANopen-to-Ethernet gateway and control unit offers IP65, IP67, or IP69K degree of protection. It enables connection of up to eight end devices or junction box modules via the eight M12 ports. Thus, connection of up to 126 devices on the CANopen site is possible. Also included is an Ethernet switch. A central configuration management via EDIP enables a simplified device replacement.

The stainless-steel Flowave Type 8098 flowmeter is based on the SAW (surface acoustic waves) technology and is designed for applications with high hygienic demands. The device includes a display showing the measured flow value. Optimal measurement results can be achieved with homogeneous liquids, free of air and solid particles.

Figure 3: Flowave Type 8098 SAW flowmeter (Source: Bürkert)

CANopen communication, parameterization via the Communicator, and the Wi-Fi connectivity are given. An Atex certification for explosive environments is available as an option.

Figure 2: CANopen-to-Ethernet gateways ME43 and ME63 (Source: Bürkert)

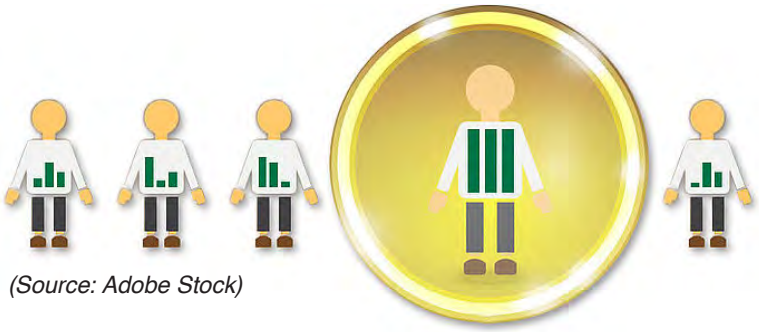
The valve island Type 8653 Airline Field is developed for applications in process automation. Diagnostic functions can be visualized on the LCD display in clear text and as symbols. This facilitates assignment of the displayed messages and helps to save time during the start-up and in the maintenance phase. The diagnostic messages are also available in the controller, which enables an overview of the plant status. For the CANopen connection, the circular 5-pin M12 connector is used. The device can be programmed by means of the Communicator software.

The ME61 is a 3,5-inch process view display for process parameters. The device provides a CANopen interface via the M12 connector. Up to four process parameter and status information fields can be displayed. The device can be set up to display the required information using the GUI-based Configurator tool. Integration and combination with other devices are possible using in the EDIP platform. Mounting options for DIN rail clip, pipe mounting, and wall mounting with a magnetic holder are offered.

Figure 5: ME61 process view display (Source: Bürkert)

CANopen FD devices identification via LSS

This article introduces the layer setting services (LSS) used to configure network-ID, node-ID, and bit-timing of devices in CANopen FD systems. The according specification is intended to be released in summer 2021.



(Source: Adobe Stock)

CANopen devices require a node-ID in the value range from 1 to 127 used for unique addressing in different CANopen services. The layer setting services (LSS, defined in CiA 305) allow to assign the node-ID and the bit rate via the CANopen network. LSS is used for CANopen devices without a hardware interface (e.g. DIP-switches, EIA-232) or for applications requiring a high level of plug-and-play support. In September 2017, CAN in Automation (CiA) has published the CiA 1301 CANopen FD application layer and communication profile. Since then, the CiA SIG (special interest group) LSS FD discusses how CANopen layer setting services should be adapted to CANopen FD.

The basic requirement for participating devices is the availability of the identity object (1018_h) with four implemented 32-bit sub-indexes: vendor-ID, product code, revision number, and serial number. In combination, the sub-indexes provide a 128-bit value, which is called LSS address. The LSS address is a unique number for any CANopen (FD) device. The vendor-ID (object 1018_h, sub-index 01_h) is mandatory for all classic CANopen and CANopen FD devices. CiA assigns the vendor-ID uniquely to the device manufacturers.

LSS distinguishes between an LSS manager (typically residing in the host controller) and the LSS server, formerly named the LSS master and the LSS slave. The terms LSS manager and LSS server have to be finally approved by the CANopen (FD) community. In a CANopen network, the LSS Fastscan service is used to identify the unconfigured LSS servers. LSS Fastscan service requires up to 128 messages to be exchanged. Using the new service for CANopen FD (LSS switch state selective FD) the complete LSS address can be identified after exchange of maximum 33 messages. This service replaces the LSS switch state selective service in CiA 305. It will be specified in CiA 1305 CANopen FD layer setting services (LSS) and protocols. Benefited from the larger payload of CANopen FD, the complete 128-bit LSS address can be sent in one request.

In case several unconfigured LSS servers exist in a CANopen FD system, they can be identified by means of the LSS switch state selective FD service. All unconfigured nodes will handle the switch state selective FD requests from the LSS manager. All other (configured) nodes will ignore such requests. This service allows the LSS manager to select LSS servers based on their LSS address or portions thereof.

To fulfill the service, the 128-bit LSS address was divided into 32 pieces (nibbles) of four bit each. The nibbles are numbered from 0 to 31 (most significant bit to lowest significant bit). The LSS manager consequently asks the LSS servers for the values of each nibble. 16 messages with the CAN-IDs from $07D0_h$ to $07DF_h$ are used as possible feedback. When the LSS manager requests the value of the first nibble, the LSS servers reply with $07D0_h$ if their first nibble is zero, $07D1_h$ if it is one and so forth until $07DF_h$ if their first nibble is $0F_h$. Then, the LSS manager takes the first response (all others are ignored for this cycle) and packs the first nibble value into the next request. The LSS servers with the first matching nibble inform the LSS manager about the second nibble value using the 16 messages with the mentioned CAN-IDs. Then, the LSS manager packs the detected first and second nibble value (from a node responded first) into the next request. This cycle is repeated until all nibbles have been processed and a single, unconfigured LSS server is identified. Then, the identified LSS server is switched into the LSS configuration state in which a network-ID and a node-ID can be assigned.

To decrease the boot-up time in CANopen FD systems that may be modified by the end user, the LSS manager could store LSS addresses that have been identified. On each power-up, the LSS manager could try those LSS addresses first and if there is then still an unconfigured LSS server left in the system, the LSS switch state selective FD cycle is started.

Example scan cycle

In the example (see Figure 1) the LSS manager sends a request to check the value of nibble number 3 (nibno = 3_h). The field portion (a portion of the LSS address that is already determined) contains the value 006_h (from nibble 0 to nibble 2). The LSS manager uses the CAN data frame with the fixed CAN-ID $7E5_h$.

If the nibble 0 to nibble 2 of a server's LSS address match with the requested value, the server responds. The response informs about the server's nibble 3 value via the used CAN-ID calculated as follows: *CAN-ID = $7D0_h$ + value of the nibble.* The value of the requested nibble 3 in the example is D_h. Thus, the LSS server responses using the CAN-ID $7D0_h$+ D_h = $7DD_h$. The LSS manager processes the response and packs the value of the nibble 3 into the next request. The LSS manager sends the next request for nibble number 4 (nibno = 4_h). Now, the portion LSS address contains the value $006D_h$. The LSS server handles the request as described above.

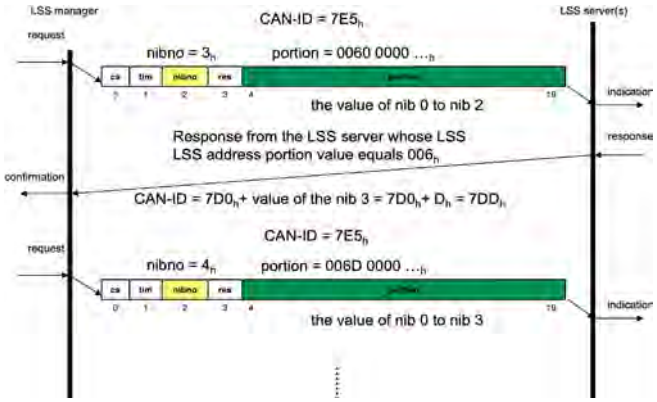


Figure 1: LSS manager request for nibble number 3 (Source: CAN in Automation)

When the nibble number in the LSS manager request reaches the value 32, it means that this is the final request. As there is no nibble with the number 32, this value indicates that the field portion contains an already determined LSS address. The corresponding LSS server sends now the final response with the fixed CAN-ID $7E4_h$, and switches itself into the LSS configuration state. In this state, the network-ID and node-ID of a CANopen FD device can be configured.

If the LSS manager knows the complete LSS address of an LSS server on the network, a single request is sufficient to select one LSS server. The LSS manager sets the requested nibble number to 32. The portion LSS address equals the known LSS address of the LSS server. The selected LSS server replies with the CAN-ID $7E4_h$. After switching of the LSS server into the LSS configuration state, the network-ID and node-ID are configurable.

If only a part of the LSS server's address is known, the LSS manager packs the known portion into the request and scans for the unknown nibbles according to the procedure as shown above.

Summary

The new service LSS switch state selective FD makes the operation sequences for identifying of LSS server simpler and more flexible. The CiA 1305 CANopen FD layer setting services and protocols will be expectedly released by CAN in Automation in the summer of this year. The CiA 1305 specification is not backward compatible to the CiA 305, as CAN FD is not backward compatible with Classical CAN. The LSS switch state selective FD mechanism can also be applied on different CAN FD based systems using other higher-layer protocols. ◀

Author

Yao Yao
CAN in Automation
pr@can-cia.org
www.can-cia.org

CAN XL documents under development

CAN XL is more than just a data link layer plus a physical medium access sub-layer. CAN XL comprises also higher-layer protocol specifications and add-on services.

Originally, in-vehicle network experts from Volkswagen initiated the CAN XL development. In the beginning, the focus was on the CAN XL data link layer featuring a data field ranging from 1 byte up to 2 048 byte. In the CAN XL protocol, the priority indication and the frame acceptance are separated. In Classical CAN and in CAN FD, the CAN-ID field provides both functions: bus access priority and frame filtering. In CAN XL, there is the 11-bit priority field and the 32-bit acceptance field containing address or frame content information.

The CAN XL protocol also embeds OSI (open system interconnections) layer management information. This includes the Service Data Unit Type (SDT) field and the Virtual CAN Identifier (VCID) field. Higher layers provide this information to indicate to the receiving nodes the used next higher OSI layer respectively to run several communication applications in parallel on the same cable. The SDT field is similar to the Ethertype function.

OSI layer management information is nothing new. A typical example is the setting of bit-timing parameters. The software driver of the host controller can do this statically, when it initiates the CAN controller. Another option is a separate configuration interface, e.g. DIP switches or USB or second CAN interface. Alternatively, you can use the same CAN interface running a dedicated protocol, such as specified in CiA 305 for CANopen applications.

The CAN XL protocol controller can be connected to any CAN transceiver with an attachment unit interface (AUI) as specified in ISO 11898-1. Additionally, it features a PWM (pulse width modulation) coding and decoding to be connectable to CAN XL SIC (signal improvement capability) transceivers.

SIG CAN XL and its TFs

The CiA (CAN in Automation) special interest group (SIG) CAN XL coordinates all these specification activities. The physical layer is developed within a task force (TF) reporting to the SIG. There is also the TF higher-layers specifying the SDU types and the CAN XL frame fragmentation, which can be used to improve the real-time capability of the CAN XL communication in case of transmitting frequently blocks of long frames. The TF also supports the extension of the ISO 15765-2 transport protocol for CAN XL frames. Another TF has been established to specify a CAN XL data link layer security protocol. First work drafts have been released for CiA-internal discussions.

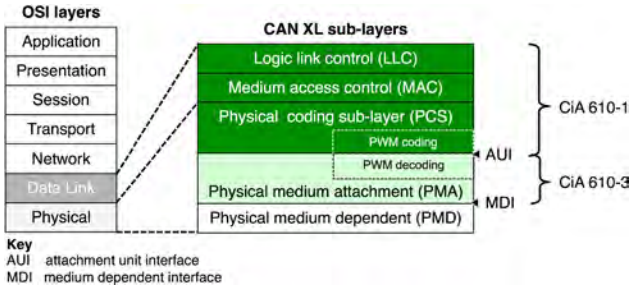


Figure 1: CAN XL lower layers and its mapping to the OSI model (Source: CAN in Automation)

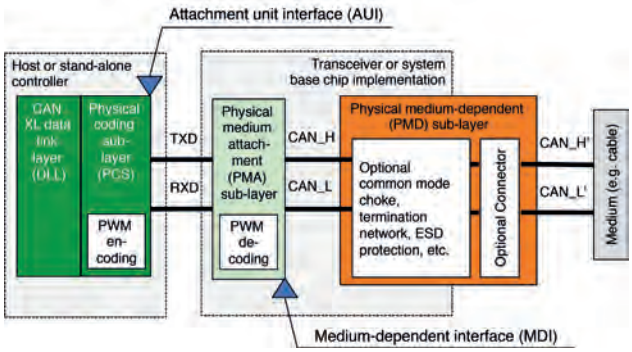


Figure 2: CAN XL lower layers implementation example (Source: CAN in Automation)

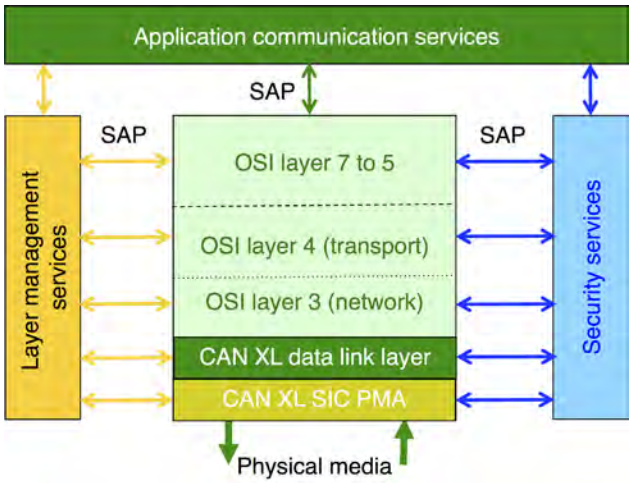


Figure 3: Extended OSI model for CAN XL with additional service access points (SAP) for layer management information as well as security (Source: CAN in Automation)

The set of CAN XL specifications comprises also device and network design recommendations. When the series of CAN XL specifications and test plans are released ▷

Table 1: Planned CiA documents for CAN XL (Source: CAN in Automation)

Number	Title	Status
610-1	CAN XL specifications and test plans – Part 1: Data link layer and physical coding sub-layer requirements	Work Draft
610-2	CAN XL specifications and test plans – Part 2: Data link layer and physical coding sub-layer conformance test plan	Proposal
610-3	CAN XL specifications and test plans – Part 3: Physical medium attachment sub-layer requirements	Work Draft
610-4	CAN XL specifications and test plans – Part 4: Physical medium attachment sub-layer conformance test plan	Proposal (static test)
611-1	CAN XL higher-layer services – Part 1: SDU types	Work Draft
611-2	CAN XL higher-layer services – Part 2: Multi-PDU	Work Draft
611-3	CAN XL higher-layer services – Part 3: Generic transport layer requirements	Proposal
611-4	CAN XL higher-layer services – Part 4: Generic transport layer conformance test plan	No proposal
612-1	CAN XL guidelines and application notes – Part 1: System design recommendations	No proposal
612-2	CAN XL guidelines and application notes – Part 2: PWM coding implementation guideline	Proposal
613-1	CAN XL add-on services – Part 1: Simple/extended content (SEC) indication	Proposal
613-2	CAN XL add-on services – Part 2: Security	Proposal
613-3	CAN XL add-on services – Part 3: LLC frame fragmentation	Proposal

as Draft Specification Proposals (DSP), the SIG CAN XL will start to develop such recommendations. CiA is also planning CAN XL plugfests testing the interoperability of different CAN XL node implementations. A first one should take place in this summer depending on the Covid-19 pandemic situation.

Author

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

CANopen FD use cases

CANopen FD allows efficient and simplified embedded networking. It comes with interesting features added to classic CANopen networking by keeping the robustness and scalability. This article examines why and when choosing CANopen FD.

(Source: Adobe Stock/CiA)

Modern applications demand network design flexibility. Even the end user shall have the option to modify the application or network setup. Thus, a dynamic handling of communication coherences between the devices in the network is needed. Additionally, increased requirements for safety-relevant or secure communication demand a high data throughput; not only during configuration and maintenance, but also during system runtime. Furthermore, requirements derived from condition monitoring or IoT (Internet of Things) applications, demand an increased communication bandwidth on embedded level. The new features, added to CANopen FD, allow very efficient embedded networking, today and tomorrow; as illustrated by means of the following examples.

Control of multi-axis systems

In several applications the synchronization of various tasks is requested. For example, in multi-axis systems some axis shall start with their movements at the very same time. In Classical CAN-based networking, this task can be solved. For starting synchronized movements, the axis that shall operate synchronously for example can use a synchronized time base or a specific global event as trigger. In CANopen FD, extended PDOs provide a simplified solution. A single CAN FD data frame is utilized to transfer the drive commands in the embedded network, to all drives, at the very same time. CiA 402-6 has already specified merging several control words for several axis, in one PDO. Thus, the addressed axis are getting the commands at the very same moment and start operating simultaneously. An additional effort for synchronization is just not needed.

Security and authentication

Distributed applications that handle sensor values, on which an invoice is generated for example, have to proof that the invoice is based on the correctly-measured value. They have to assure not to use some manipulated values. Typically, in such applications, system designers have opted the classic CANopen SDO transfer. This confirmed point-to-point connection, makes sure that the right sensor value is collected from the intended sensor, that is currently in an error-free operating state. To provide all this information in a single, Classical PDO, the size of 8 byte is not sufficient. Transferring the information in several segments, may causes run-time conditions, which have to be detected. The CANopen FD PDO, with a size of up to 64-byte payload, overcomes these limitations and eases the setup of such applications.

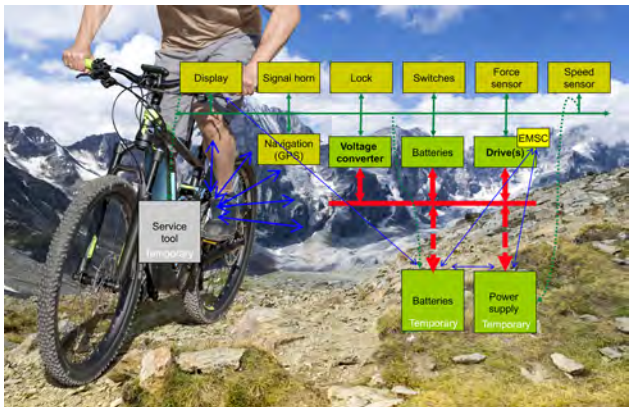


Figure 1: Pedelecs are typically based on CAN and can be modified by the end user (Source: Adobe Stock/CiA)

End-of-line production

Device manufacturers want to download the very same software, to many devices of the very same type. In classic CANopen, this requires a single SDO access to any device that shall get the latest firmware. With the enhanced functionality of the CANopen FD USDO broadcast service, up to 126 devices can be updated, with a single USDO access. For downloading 16-KiB firmware to a single device, the classic SDO would require about 9 300 CAN data frames for transmitting. Taking into account that every segment is confirmed with an 8-byte Classical CAN data frame. The number of exchanged Classical CAN data frames is even doubled. Additionally, the same effort is required for any device that shall be updated. Consequently, the time that is needed for updating the firmware on the devices is increased, proportional to the number of devices that shall be updated.

The CANopen FD USDO accelerates this use case significantly. For downloading a 16-KiB firmware to a single device, about 1 200 CAN FD data frames are required. With special regard to the segmented USDO protocol, the number of used frames is also doubled for confirming the reception of every segment. But in contrast to classic SDOs, the USDOs utilize a CAN FD frame for confirmation, which is about half of the size of the Classical CAN data frame, used by the classic SDO. In CANopen FD, the protocols use a CAN FD data field, that has been adapted to the real required payload.

In case such a scenario is executed at a nominal bit rate of 500 kbit/s, by using the CANopen FD segmented USDO protocol without bit rate switching, the firmware update would be handled in less than half of the time, compared to the classic CANopen segmented SDO protocol. But up to now, the real power of the USDO has not been applied. Classic CANopen SDO protocol is only applicable in a unicast session. Therefore, any additional device that requires a new firmware, adds the full time for a single device firmware download to the entire procedure. In CANopen FD, it does just not care how many devices in the network need a firmware update. Even in the worst case that the maximum number of devices (126) need an update of the very same firmware, the time for updating this firmware remains unchanged. Thanks to the USDO broadcast services, the time for updating devices' firmware does not depend on the number of devices, in case the devices are of the same type and need the same firmware. Another booster for this scenario, utilizing the CAN FD bit rate switch, has not been considered, yet, and would reduce the time for this scenario additionally.

System maintenance

The new USDO (broadcast) service saves system maintainers a lot of effort and time. In case system maintainers intend to get familiar with an application; e.g. they like to verify whether the correct devices of the correct origin and configuration are installed, the USDO broadcast ▷

services accelerate this task enormously. A big share of this acceleration is achieved by omitting a lot of time-outs; e.g in case some devices have a slow reaction time or are simply not attached to the system. All these time-outs would be experienced in case a classic CANopen SDO would be used. But not only the USDO multicast or broadcast capability is beneficial in this scenario. Also, the fact that in contrast to classic CANopen SDOs, CANopen FD devices can handle multiple USDO transfers in parallel, simplifies and accelerates this task.

Diagnostic tasks are simplified by the extended CANopen FD EMCY write service. A listing of current device errors, is provided in any device. The error information provides details such as the type of error, the chronological order of the errors, or the location of the error within a more complex device. This may reduce the time for diagnostics, removing the errors, and thus down-times of the entire application, as well.

CANopen FD background information

CANopen FD is an advancement of CANopen, a communication system based on CAN FD. It comprises higher-layer protocols and profile specifications. CANopen FD has been developed with special regard to making use of CAN FD's higher data throughput, by keeping the key-attributes of CANopen. CANopen FD offers a high data throughput, advantageous for data demanding cloud applications. Embedded systems that can be modified by the end user during system run-time, benefit from the new USDO that allows a dynamical, simple establishment of cross-communication, in unicast and broadcast. Please find here more technical-related details regarding CANopen FD.

Applications, modified by the end user

An increasing number of applications have the requirement that the end user can change the setup of the application. Especially in energy management applications such kind of requirements are typical. The end user adds or removes batteries, power supplies (chargers), or further types of energy sinks and sources. Depending on the kind of connected devices, a lot of cross communication between the devices need to be established dynamically. Thus, all devices in the system get familiar with the current operation mode and setup of the system, and are enabled to provide their functionality to the application, in a correct and save way.

In principle, these kinds of requirements can be managed in a classic CANopen environment. But typically, comprehensive evaluations are needed such as, how potential network setups could look like and how they could be treated, by means of CANopen, which had been designed for rather static applications in mind. In an CANopen FD based environment, of course evaluations have to be done, but the solutions are much simpler to be realized by the possibilities of the USDO services.
By default, any CANopen FD device attached to the application has the ability to access any other, potentially available, network participant. Therefore, independently which devices are connected, any device can get familiar with the current network setup and learn by accessing all other network participants, which functionality shall be provided to the application. No human interaction is needed anymore, neither by a skilled technician, nor by a CANopen FD expert. With the CANopen FD devices, everything can be treated dynamically, by means of basic CANopen FD communication capabilities. Thus, a lot of resources in system design and maintenance can be saved.

Internet of Things applications

More and more applications need to submit data to web-based applications. This includes e.g. condition monitoring or system maintenance. In these kinds of applications, edge-gateways provide data, generated deeply in the embedded network of the application, to cloud-based applications. One tricky aspect in these applications is that it is not necessarily known at the time of the system design, which kind of embedded data will be needed in the cloud, in future.

CANopen FD USDO services own the ability to establish communication channels to any device in an embedded network, dynamically during system runtime. Thus, any data element in the embedded network level, is available in principle, on demand, just in time. An exhaustive assessment, which kind of data element could be needed now, or will be needed in future, can be omitted. CANopen FD simplifies therefore the integration of embedded networks, into the cloud.

Summary

CANopen FD comes with a lot of interesting features, added to the well-known classic CANopen. They simplify CAN-based embedded networking by keeping the robustness and scalability. CAN FD hardware has been made available in a broad range and also CANopen FD protocol stacks are offered by several companies. Thus, everything is available to start in the next generation of CANopen-based embedded networking. CAN in Automation offers a range of CANopen FD based webinars and explains how to migrate from classic CANopen to CANopen FD. ◀

Author

Reiner Zitzmann
CAN in Automation
pr@can-cia.org
www.can-cia.org

CAN decoder warns for malicious attacks

The open-source Sigrok project is a set of drivers and tools. It provides a desktop oscilloscope and logic analyzer UI (user interface) that can control different instruments (from Siglent, Rigol, and others).

The UI runs on Mac OS, Windows and Linux and is called Pulseview. Integrated is also a command-line tool for batch decoding, useful in an automated test environment. Pulseview has an API (application programming interface) for protocol decoders. Recently, a decoder for CAN has been introduced.

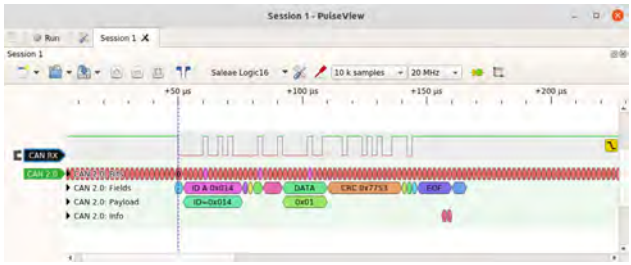


Figure 1: Decoder screenshot of a CAN frame (Source: Canis Automotive Labs)

Figure 1 is a screenshot of the decoder showing a CAN frame. Here, the Pulseview interface runs on Ubuntu Linux. The logic analyzer hardware used here is a 16-channel Saleae Logic16. But the available USB logic analyzers that cost less than 10 US $ with eight channels and a sample rate of up to 20 MHz are also suitable for use with CAN. A falling-edge trigger condition is typically used with CAN (this is the sync point for the protocol). A pre-trigger buffer enables the decoder to see at least ten recessive bits to know that the next dominant bit is a new frame.

The decoder shows four lines of details about a CAN frame:

- The raw bitstream (including stuff bits)
- The decoded CAN fields
- The decoded CAN-ID and payload bytes
- An information line showing protocol events and warnings

View of details

Pulseview shows as much details as fits into an item for a given time scale, but a tooltip appears with the full data if the mouse pointer hovers over an item. For example, the value of the 4-bit DLC (data length code) field with a tooltip is shown in Figure 2.

The decoder also checks the frame for valid fields and marks when an error is detected. For example, it will show in the warning line when the received CRC (cyclic redundancy check) does not match with the calculated CRC, when

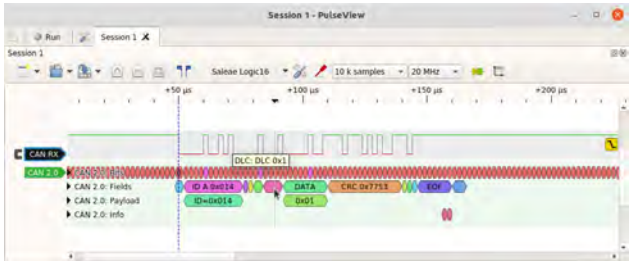


Figure 2: Value of the 4-bit DLC field shown with a tooltip (Source: Canis Automotive Labs)

the ACK (acknowledge) field is not 0, when a stuff error has been detected, and so on. It also shows an active error frame including the superposition, the error delimiter, and the IFS

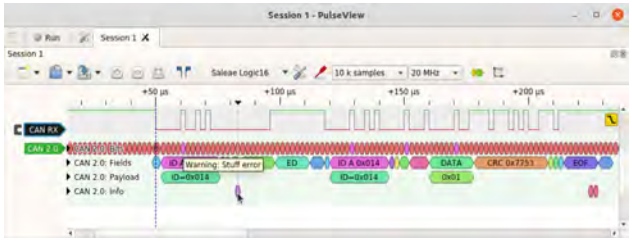


Figure 3: Warning about a stuff error (Source: Canis Automotive Labs)

(interframe space) field following an error frame.

The warning as shown in Figure 3 is a stuff error – the result of an error being signaled by another CAN controller. The decoder shows the error flag (which includes the superposition of dominant bits from many controllers) and the error delimiter. The trace also shows the frame being re-transmitted successfully.

The double-receive event is a particularly interesting property of CAN. Because a frame is received one bit-time before it is transmitted, it is possible that an error in the last bit of the EOF (end of frame) causes the transmitter to detect an error and retransmit the frame, leading to it being received twice. This is not a bug in the CAN protocol: it is an inevitable consequence of implementing an atomic broadcast protocol (something that most other communication protocols do not even attempt to provide, which is one reason why CAN is such a superbly reliable fieldbus protocol).

As seen in Figure 4, the decoder warns of this specific event (double receive). This event should happen rarely (a bit error must occur exactly at the last bit of EOF). But it can be engineered to occur by an attack on the bus: by deliberately injecting a dominant bit at the last bit of EOF, an attacker can force the frame to be retransmitted and ▷

Figure 4: Warning about a double receive (Source: Canis Automotive Labs)

received twice. If the frame being targeted contains an event data, then that event will be acted upon twice by receivers, which could cause all kinds of things to go wrong – the very purpose of a malicious attack.

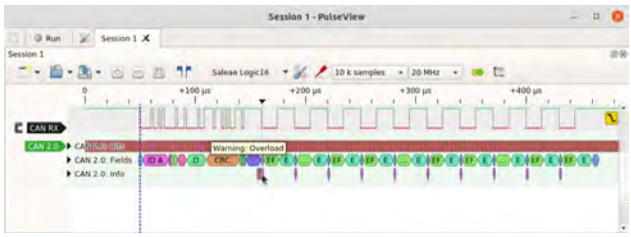


Figure 5: Warning about an overload frame (Source: Ian Tabor)

The decoder also shows when there is an overload frame – something that should never be seen since modern CAN controllers never generate these frames. The screenshot in Figure 5 shows a frame that is sent, but then a sequence of overload frames is injected to hold all the CAN controllers in an overload loop. This is a clear indication of a type of denial-of-service attack on the CAN network. In this case it was carried out by the CANhack toolkit. The CANhack toolkit is an open-source library for demonstrating attacks on the CAN protocol: github.com/kentindell/canhack.

The protocol decoder is designed to help spot these events from a logic analyzer trace – it can see things that a simple list of received CAN frames would not show. But it also can interface to CAN frame logging tools. The decoder has an option to export CAN frames in a packet capture format (called "pcapng") that tools such as Wireshark can process. A trace of many frames can be shown in Wireshark as a conventional list of frames. For example, the screenshot in Figure 6 shows the trace of a pair of CAN frames sent roughly every 100 ms.

When the exported packet capture file is read in to the Wireshark tool, it is shown as a simple list of frames (see Figure 7).

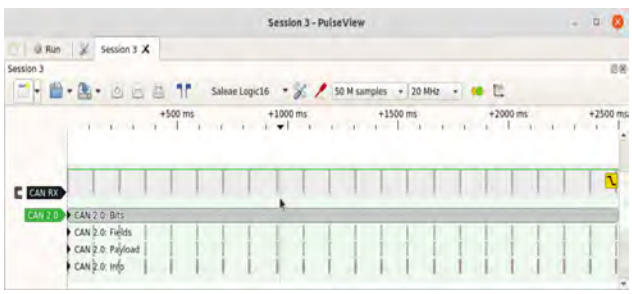


Figure 6: Trace of a pair of CAN frames sent roughly every 100 ms (Source: Ian Tabor)

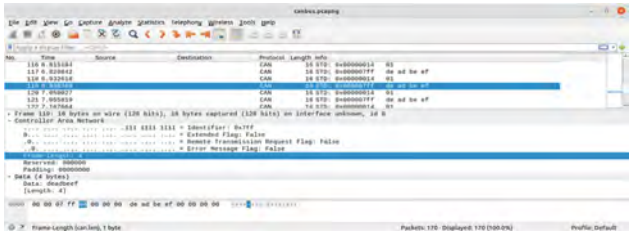


Figure 7: The exported packet capture file is shown as a frame list in Wireshark (Source: Canis Automotive Labs)

The timestamps attached to the CAN frames in the packet stream are very accurate. These are useful when hunting for a particular incident in the frame view of the Wireshark (or other tools) to navigate within Pulseview to find details of what was happening on the wire around an incident.

Unveiling hidden problems

The decoder has already helped one developer to solve a problem with their system. Ian Tabor (@mintynet on Twitter) is a car hacker who has developed a low-cost "car in a box" system for people to practice hacking. The hardware includes the ability to send CAN frames from three different buses to a monitoring bus via an MCP2515 CAN controller from Microchip. The driver was running very slowly and unable to sustain throughput that was needed. But Pulseview was able to show where the time was going: the CAN protocol decoder showed the CAN frames and the Pulseview SPI decoder (serial peripheral interface) showed where the SPI transactions were taking place. The screenshot in Figure 8 shows the situation before.

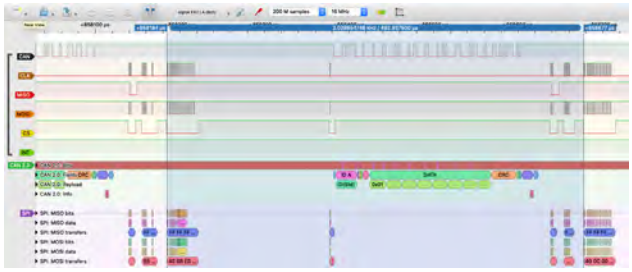


Figure 8: CAN traffic before driver optimization (Source: Ian Tabor)

The screenshot in Figure 9 shows the situation after the drivers were optimized, reducing the time between frames from nearly 500 µs to just over 300 µs.

Figure 9: CAN traffic after driver optimization reducing the time between frames (Source: Ian Tabor)

The tool's availability

The source code to the CAN protocol decoder is available in the CANhack toolkit repository on Github at github.com/kentindell/canhack. The decoder is in the folder src/can2. The best way to install the Sigrok tools (Pulseview and Sigrok-cli) is to download them directly from Sigrok. More details on setting up the decoder can be found here.

CAN board for Raspberry Pi Pico

The CANPico board has been recently released by Canis Automotive Labs. It integrates a Microchip MCP2517/18FD CAN controller with a 2-KiB buffer and the Microchip MCP2562FD CAN transceiver. Jumpers are available for connection of a 120-Ω CAN termination resistor and for disabling of transmit access to the CAN network (listen-only access). There is also a 6-pin header for connection of a logic analyzer (e.g. the CAN2 protocol decoder) or oscilloscope. The included Trig pin can be set in order to trigger the logic analyzer on a specific CAN-ID or a CAN error frame.

Along with the board is a pre-built Micropython SDK (start development kit) firmware, with a CAN API that includes priority-inversion-free drivers, time-stamping (both send and receive), control of CAN-ID filters, and a CAN bit-rate setup. The board is ready for order online from SK Pang. It is shipped with a Raspberry Pi Pico and the pre-installed firmware. More detailed information is available here.

of

Author

Ken Tindell
Canis Automotive Labs
ken@canislabs.com
canislabs.com

Comparing CAN, CAN FD, and Ethernet

This analysis compares Classical CAN, CAN FD, and and Ethernet communication with focus on a decentralized battery management system.

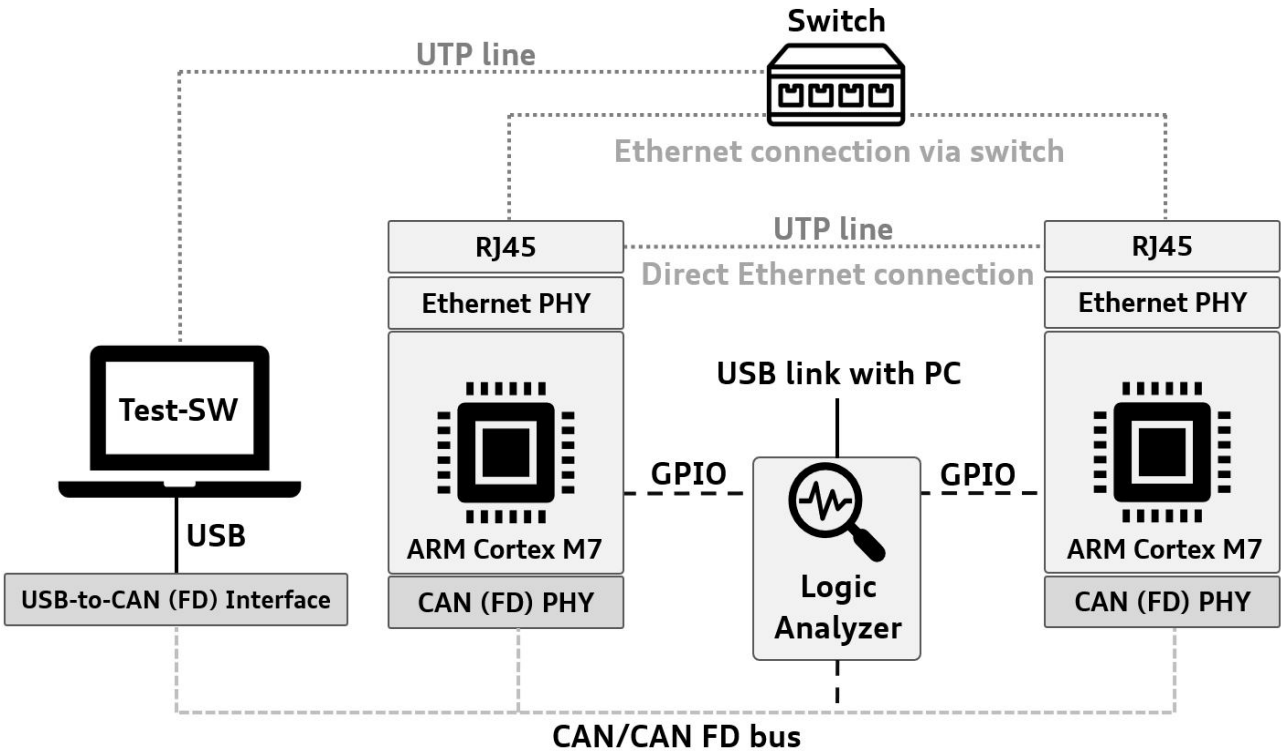


Figure 1: Test setup for comparative analysis of CAN, CAN FD, and Ethernet (Source: OTH Regensburg)

Networked control systems such as battery management systems, smart grids, or vehicular systems, consist of sensors, actuators, and controllers linked via a common communication line. The system control can be distributed among several nodes thus building a decentralized control system enabling a communication-based coordination of the control tasks. Nodes can be added or removed even after an initial installation, which offers the required flexibility for different applications.

A communication network can cause unpredictable delays which can affect the system control. For CAN communication, e.g., only the latency of the highest prioritized data frame can be determined. For the remaining data frames, the delay depends on the situation on the network and is not predictable. These network-induced delays may increase the time jitter of the control loop, which consequently can lead to instability. In addition, possible data or information loss or data manipulation, endanger the control coordination. Therefore, the data rate and the reliability of the underlying communication network are key factors of the networked control system. In addition, the processor load caused ▷

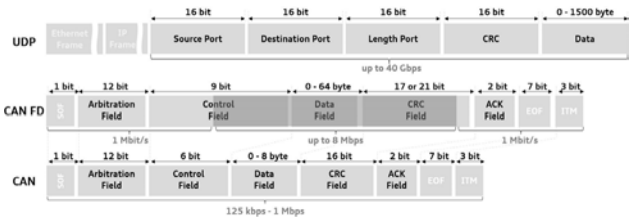


Figure 2: Structure and size of the UDP, CAN FD, and CAN frames and the maximum transmission rates (Source: OTH Regensburg)

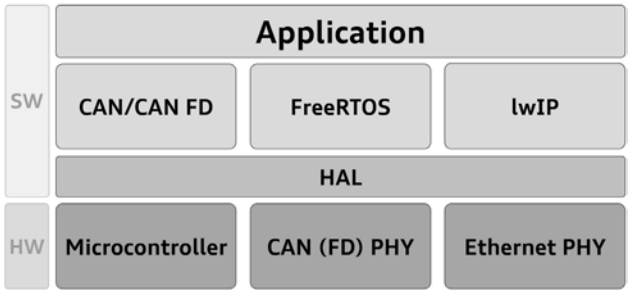


Figure 3: Software components and the interface between them and the hardware (Source: OTH Regensburg)

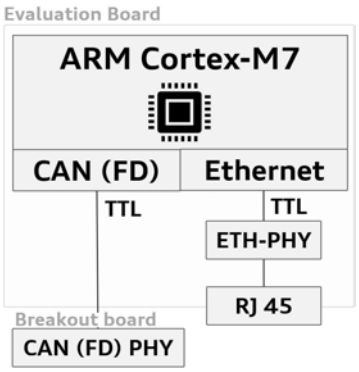


Figure 4: Hardware components used to implement CAN, CAN FD, and Ethernet communication (Source: OTH Regensburg)

by the communication is relevant as it affects the calculation of system states and the setting of control parameters.

Energy required for the communication network influences the system efficiency in a respective application. Energy efficiency, small latency, and reliability are the key features for the communication networks.

The decentralized battery management system (DBMS) is an example application for networked controlled systems [1].

The DBMS consists of renewable energy generators, a variable number of different batteries, and varying loads. For battery control, battery-specific condition parameters are communicated regularly, which allows to adjust the required charging/discharging power of the batteries. Additionally, current, voltage, and temperature values are measured in millisecond intervals. Each data packet comprising few bytes contains a time stamp and is sent to all participating nodes forming the basis for the collaborative system control. Within the DBMS, it is therefore required to regularly send frames with few data bytes quickly, reliably, and without errors in order to achieve system-wide data consistency.

Examined networks

Classical CAN is widely used in distributed embedded systems. Its limited communication bandwidth (up to 1 Mbit/s) and payload (user data) size (up to 8 byte) restrict the applicability in increasingly complex electronic systems (Figure 2). CAN FD comes with higher data-transfer rate (up to 8 Mbit/s) and larger payload size (up to 64 byte).

Ethernet offers data rates up to the Gbit/s-range via a twisted pair (TP). In embedded systems, 100BASE-TX with 100 Mbit/s is most common, since higher data rates also increase processor and memory requirements. It offers a payload size of up to 1 500 byte and provides low latency but is also more complex compared to Classical CAN and CAN FD. Ethernet-based solutions offer various protocols. In this article the user datagram protocol (UDP) is considered as it is a relatively simple compared to the transmission control protocol (TCP). It avoids confirmation of correct frame reception and thus supports unicast, multicast, and broadcast communication. The size of the UDP message header (8 byte) is significantly reduced compared to the up to 60-byte ▷

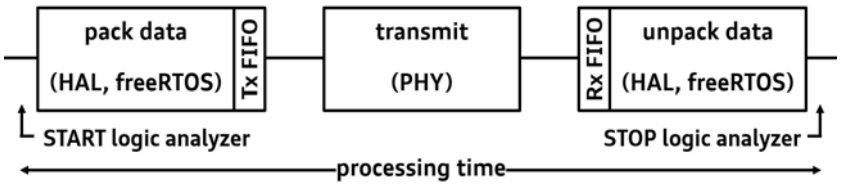


Figure 5: Measurement of frame processing time: The start pin of the logic analyzer is set before the frame is created and the stop pin is set after the frame is completely received (Source: OTH Regensburg)

header of the TCP. In the scope of this article, the UDP/IP protocol stack is examined and is only one of several options.

For the evaluation of the energy efficiency, the maximum power consumption of the communication technologies is measured. To evaluate the transmission reliability, the bit error rates (BER) and the residual error rates (RER) are determined. Furthermore, the frame processing time and the processor load of each communication technology are measured as both influence the system control. Since networked control systems may consist of numerous participants, the behavior of the communication technologies under high network load is investigated.

In this article, theoretical comparisons have been made for a substantiated evaluation of the communication technologies. Data sheets, existing literature, and simulations are referenced. In addition, comparative tests within a hardware test setup enabled practical, realistic results, especially for transmission speed, error susceptibility, and behavior under high frame load.

Test environment setup

The basis for the comparative analysis is the software implementation (Figure 3) of the communication technologies and a test environment (Figure 1). The test setup consists of software and hardware components.

Software implementation: For a direct comparative analysis, the three communication technologies are utilized and measured individually. In addition, combined operation enables direct comparisons under identical conditions. The real-time operating system FreeRTOS [2] is applied in order to support multi-threading (Figure 3). Classical CAN and CAN FD use the same hardware module on the micro-controller and are therefore combined into one thread. To switch between CAN and CAN FD, only a few bits of the control field in the data frame are modified. In the following, CAN (FD) describes both CAN and CAN FD. Ethernet communication requires a software design that supports the protocols from the physical to the transport layer. The TCP/IP stack lightweight IP (lwIP) was developed for embedded systems and offers advantages in efficiency and program scope [3], [4]. The stack supports several application program interfaces (APIs). It provides functions to initialize the UDP module and also handles the Internet Protocol (IP), e.g., setting the IP address, subnet mask, or gateway mask. The UDP thread is created after initialization and manages the sending and receiving of messages. The initialization of the periphery is performed by functions of the hardware abstraction layer (HAL).

Hardware components: For the hardware realization, the evaluation board STM32H743ZI [5] and an external CAN transceiver [6] are used (Figure 4). The evaluation board integrates an ARM Cortex-M7 processor and provides two CAN (FD) modules and one Ethernet module. Furthermore, there is an Ethernet PHY and a RJ45 connector on the board. For CAN (FD) only the logic modules are available, therefore an external CAN transceiver is added.

Test setup: Two micro-controllers with corresponding interfaces and a test PC are connected (Figure 1). The test PC monitors the network and performs the tests. The micro-controllers are connected to the CAN (FD) network via CAN (FD) transceivers. For a connection between the test PC and the CAN (FD) network a CAN-to-USB interface [7] is used. The test PC and the micro-controller integrate an Ethernet PHY and are connected to the Ethernet network via an unshielded twisted pair (UTP) line. The Ethernet network is connected via a switch. For the determination of the Ethernet frame processing time, the micro-controllers are also directly connected to each other via the RJ45 interface. For the frame-processing time measurement, a logic analyzer is used, which is connected to the test PC via USB. Evaluation criteria and acquisition methods

For the comparative analysis, the following evaluation criteria are determined:

- Frame processing time
- Processor workload
- Energy consumption
- Error rate
- Rx-Fifo load

All comparative measurements are performed with a transmission speed of 500 kbit/s for CAN; 500 kbit/s or 1 Mbit/s as well as 4 Mbit/s for CAN FD; and 100 Mbit/s for Ethernet.

Frame processing time: For the comparison of the frame processing time, the same number of user data is transmitted at an identical 1,5-m link between a sender and a receiver. The frame processing time is measured with a logic port that monitors the start and stop pin. It consists mainly of the transmission time and additionally of the computing time for packing/unpacking the frame. The start pin is set to high immediately before the send command, while the stop pin is set after the frame has been completely received (Figure 5).

Processor workload: For system control, operating parameters are recorded, system states are calculated, and the corresponding data are managed by the micro-controller. Communication, in particular the preparation of frames, sending and receiving of frames, also places a load on the micro-controller. For this reason, the processor workload allocated to communication, is determined. The measurement is divided into workload caused by the initialization and the sending or receiving of frames.

References

[1] A. Reindl, H. Meier, M. Niemetz, "Scalable, Decentralized Battery Management System Based on Self-organizing Nodes", in: Brinkmann A., Karl W., Lankes S., Tomforde S., Pionteck T., Trinitis C. (eds) Architecture of Computing Systems – ARCS 2020. Lecture Notes in Computer Science, vol 12155. Springer, Cham, https://doi.org/10.1007/978-3-030-52794-5 13, 2020.

[2] FreeRTOS Kernel Developer DOcs. https://www.freertos.org/features.html

[3] lwIP 2.1.0 — lightweight IP Stack. http://www.nongnu.org/lwip/2 1 x/index.html

[4] STMicroelectronics: UM1713 User manual — Developing applications on STM32Cube with LwIP TCP/IP stack. 2017. https://www.st.com/resource/en/user manual/dm00103685-developing-applicationson-\\stm32cube-with-lwip-tcpip-stack-stmicroelectronics.pdf

[5] Datasheet, STMicroeletronics: STM32H742xI/G STM32H743xI/G, https://www.st.com/resource/en/datasheet/stm32h743bi.pdf, 2019.

[6] Datasheet, Microchip: MCP2561/2FD, http://ww1.microchip.com/downloads/en/devicedoc/20005167c.pdf, 2014.pdf, KNF Kongress, 2001.

Energy consumption: The energy consumption is determined for each communication technology separately using the Power Consumption Calculator (PCC) from STMicroelectronics. The calculation is based on the data sheet information. The CAN (FD) and Ethernet sequences are analyzed. As Classical CAN and CAN FD use identical peripherals, they are examined collectively in the CAN (FD) sequence. Energy consumption in run, idle, and sleep mode is determined.

Error rate: Correct data transmission is the basis for the effective network control. The considered error rate focuses on errors occurring during transmission or processing of frames. A distinction is made between detected (handled) errors and undetected (not handled) errors. The latter may have damaging consequences. To determine the probability of occurrence, the bit error rate (BER) and the residual error rate (RER) are defined. The BER is the number of bit errors in relation to the total number of bits sent (Equation 1).

$$\mathrm{BER} = \frac{\#\mathrm{Bit\ errors}}{\#\mathrm{Bits_{total}}}$$

The RER is the number of undetected, erroneous frames in relation to the total number of frames, whereby the residual package error (RPE) is the number of undetected frames with errors (Equation 2).

$$\mathrm{RER} = \frac{\mathrm{RPE}}{\#\mathrm{Messages_{total}}}$$

For comparison of error rates, existing literature, and data sheets are referenced.

Rx-Fifo load: A high transmission rate with a large frame volume can lead to information loss. The frames are first stored in the corresponding Rx-Fifos and subsequently processed. If the frames are processed too slowly with constantly new incoming frames, an Rx-Fifo overflow may occur and entries that have not yet been processed are overwritten. The load of the Rx-Fifo is investigated in case of a high frame load. Therefore, the test PC generates a correspondingly high quantity of numbered test frames. ◀

To be continued: This article is split in two parts. In the next issue of the CAN Newsletter magazine, you can read Part 2. This article was originally presented as a paper at the Embedded World Conference 2021 Digital.

Authors

Andrea Reindl, Daniel Wetzel,,Norbert Balbierer, Hans Meier, Michael Niemetz
Faculty of Electrical Engineering and Information Technology - Ostbayerische Technische Hochschule Regensburg
Contact the authors via andrea.reindl@st.oth.regensburg.de
www.oth-regensburg.de
Sangyoung Park
Smart Mobility Systems - Technical University of Berlin
sangyoung.park@tu-berlin.de
www.sms.tu-berlin.de

17th international CAN Conference

icc

Registration is open

June 14 to 17, 2021

14 | 15 | 16 | 17

Opening

12:30 Holger Zeltwanger CAN in Automation

Session I: Physical layer

Chairperson Holger Zeltwanger CAN in Automation

13:00 **The physical layer in the CAN XL world**
Magnus-Maria Hell Infineon Technologies

13:30 **Characterizing the physical layer of CAN FD**
Johnnie Hancock Keysight Technologies

Session II: CAN XL data link layer

Chairperson Reiner Zitzmann CAN in Automation

14:00 **Introducing CAN XL into CAN networks**
Florian Hartwich Robert Bosch

14:30 **CAN XL error detection capabilities**
Dr. Arthur Mutter Robert Bosch

15:00 **CRC error detection for CAN XL**
Dr. Christian Senger University of Stuttgart

CiA CAN Coffee (C^3)

15:30 **Chat with the speakers**

16:30 **End of day 1**

14 | 15 | 16 | 17

CiA webinars

9:00 **Interoperability of CAN XL & CAN FD** Register
Dr. Arthur Mutter Robert Bosch

10:00 **CAN FD a Vitamin Shot for SAE J1939** Register
Peter Fellmeth Vector Informatik

11:00 **Migration from classic CANopen to CANopen FD** Register
Alexander Philipp emotas embedded communication
Torsten Gedenk emotas embedded communication

Session V: CAN FD lower layers

Chairperson Dr. Frank Deicke Fraunhofer IPMS

12:30 **CAN signal improvement and designing 5-Mbit/s networks**
Tony Adamson NXP Semiconductors Netherlands

13:00 **A leightweight communication bus based on CAN FD for data exchange with small monolithic actuators and sensors**
Fred Rennig ST Microelectronics

13:30 **Improved CAN-driver**
Kent Lennartsson Kvaser

Session VI: Engineering

Chairperson Kent Lennartsson Kvaser

14:00 **Designing a CAN-to-TSN Ethernet gateway**
Nikos Zervas CAST

14:30 **Automated workflow for generation of CANopen system monitoring graphical user interfaces (GUI)**
Dr. Heikki Saha TK Engineering

15:00 **Benchmarking of CAN systems using the physical layer – car, truck, and marine case studies**
Dr. Christopher Quigley Warwick Control Technologies

CiA CAN Coffee (C^3)

15:30 **Chat with the speakers**

16:30 **End of day 3**

14 | 15 | 16 | 17

CiA open-house technical group meetings

9:00

IG J1939	SIG contrast media injector	SIG (electrical) drives	SIG special-car add-on devices
CiA 510, SAE J1939 series, ISO 11992 series, ISO 16844 series, etc.	CiA 425 series	CiA 402 series	CiA 447 series

10:30

IG profiles	SIG truck gateway	IG CANopen FD	SIG CAN FD Light
Co-ordination of CiA profiles specifications	CiA 413 series, DIN 4630, DIN 14704	CiA 13XX series	CiA 604

Keynote

Chairperson Holger Zeltwanger CAN in Automation

12:30 **Future of CAN from prospective of an OEM**
Carsten Schanze Volkswagen

Session III: CANopen testing

Chairperson Uwe Koppe MicroControl

13:15 **A new approach for simulating and testing of CANopen devices**
Mark Schwager Vector Informatik

13:45 **CANopen FD conformance testing – today and tomorrow**
Oskar Kaplun CAN in Automation

Session IV: CANopen FD

Chairperson Christian Schlegel Christian Schlegel Consulting

14:15 **A simplified classic CANopen-to-CANopen FD migration path using smart bridges**
Christian Keydel Embedded Systems Academy

14:45 **A theoretical approach for node-ID negotiation in CANopen networks**
Alexander Philipp emotas embedded communication

15:15 **CANopen FD devices identification via new layer setting services (LSS)**
Yao Yao CAN in Automation

CiA CAN Coffee (C^3)

15:45 **Chat with the speakers**

CiA open-house technical group meeting

16:45 **SIG subsea**
CiA 443

18:00 **End of day 2**

14 | 15 | 16 | 17

CiA webinars

9:00 **CAN physical layer options** Register
Magnus Maria Hell Infineon

10:00 **CAN XL and PWM coding** Register
Matthias Muth MVP

11:00 **CAN FD topology simulation** Register
Patrick Isensee vem Group

Session VII: Security

Chairperson Torsten Gedenk emotas embedded communication

12:30 **Embedded security recap**
Thilo Schumann CAN in Automation

13:00 **Achieving multi-level CAN (FD) security by complementing available technologies**
Prof. Dr. Axel Sikora Hochschule Offenburg
Olaf Pfeiffer Embedded Systems Academy

13:30 **CAN XL made secure**
Donjeté Elshani Infineon
Vivin Richards Infineon
Harald Zweck Infineon

Session VIII: CAN XL higher layers

Chairperson Dr. Arthur Mutter Robert Bosch

14:00 **IP concepts on CAN XL**
Peter Decker Vector

14:30 **Multi-PDU concept for heterogeneous backbone networks**
Christian Schlegel Christian Schlegel Consulting

15:00 **Standardized layer-management options for CAN-based networks**
Holger Zeltwanger CAN in Automation

CiA CAN Coffee (C^3)

15:30 **Chat with the speakers & Closing**

16:30 **End of conference**

From Classical CAN via CAN FD to CAN XL

Sponsors

emotas embedded communication

esd www.esd.eu

GEMAC

PEAK System

VECTOR