

March 2021

# CAN *Newsletter*

*Hardware + Software + Tools + Engineering*

*CANopen in the food and beverage industry*

*Faster drilling for faster Internet*

*CANopen object dictionary of an injector*

CANopen

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# CAN & CAN FD Connection via Ethernet

## ■ PCAN-Ethernet Gateway FD DR

The PCAN-Gateway product family from PEAK-System is designed for the transmission of CAN messages over IP networks. With a single gateway connected to a CAN bus, users can access the CAN bus using the LAN interface of their computer. In addition, different CAN buses can be connected over IP using this technology. The devices are configured via a convenient web interface. Alternatively, the JSON interface allows access via software.

The new PCAN-Ethernet Gateway FD DR is the first model supporting the modern standard CAN FD in addition to classic CAN.

### Specifications:

- AM5716 Sitara with Arm® Cortex® M15 core
- 2 GByte Flash and 1 GByte DDR3 RAM
- Linux operating system (version 4.19)
- Two High-speed CAN channels (ISO 11898-2)
  - Comply with CAN specifications 2.0 A/B and FD
  - CAN FD bit rates for the data field (64 bytes max.) from 20 kbit/s up to 10 Mbit/s
  - CAN bit rates from 20 kbit/s up to 1 Mbit/s
- Galvanic isolation of the CAN channels up to 500 V against each other, against RS-232, and the power supply

- Connections for CAN, RS-232, and power supply via 4-pole screw-terminal strips (Phoenix)
- LAN interface
  - Data transmission using TCP or UDP
  - 10/100/1000 Mbit/s bit rate
  - RJ-45 connector with status LEDs
- Monitoring and configuration of the devices via the web interface or JSON interface
- Software update via the web interface
- Reboot or reset of the device to a previous software version with a reset button
- Plastic casing (width: 45.2 mm) for mounting on a DIN rail (DIN EN 60715 TH35)
- LEDs for device status and power supply
- Voltage supply from 8 to 30 V
- Operating temperature range from -40 to 70 °C (-40 to 158 °F)

### Further PCAN-Gateway Models:

- PCAN-Ethernet Gateway DR - CAN to LAN gateways in DIN rail casing with Phoenix connectors
- PCAN-Wireless Gateway DR - CAN to WLAN gateways in DIN rail casing with Phoenix connectors
- PCAN-Wireless Gateway - CAN to WLAN gateways in casing with flange and D-Sub or Tyco connectors



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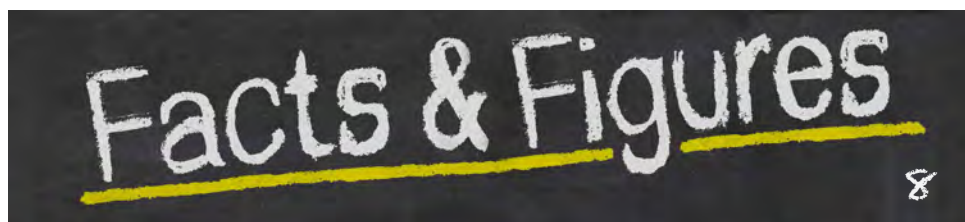
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## 17<sup>th</sup> iCC goes online

The postponed 17<sup>th</sup> international CAN Conference (iCC) will take place as an online conference from June 14 to June 17. Originally, the iCC was planned as two-day conference in Baden-Baden (Germany). However, due to the Covid-19 pandemic, it was postponed. Now, the iCC is scheduled on four half-days allowing people from Asia, Europe, and America to participate jointly at a convenient time. The iCC program has not been changed significantly. Nevertheless, the speakers will update their papers and some additional presentations will be given. At the second conference day (June 15), several CiA interest groups (IG) and special interest groups (SIG) organize "open" two-hour meetings. On June 16 and June 17, CiA will provide free-of-charge 60-min webinars to different topics. At the end of each conference day, a question & answer session is provided, where all speakers of the day are present. Since there is no tabletop exhibition, alternatively the CiA CAN Coffee (C<sup>3</sup>) chat room for informal meetings is offered. Program and details can be found on the [CiA website](#).

# CAN FD Light - From lighting to lightweight

*CAN FD Light is a network aimed at sensor/ actuator communication in automotive and non-automotive applications. The need and the advantages for a lightweight CAN-based network is proven in lighting systems for modern cars.*

The necessity for a lightweight CAN FD network became evident during the development of a system for modern car rear lights. During the development phase the usefulness of a “CAN FD Light” with rear lighting being a frontrunner surfaced while looking at the future trends in car communication systems and other fields in the industry. Communication systems with a central controller and small actuator and sensor devices have been around for many years already. The need to drive hundreds of light sources in a dynamic way and the safety and reliability requirements plus the cost pressure inherent to the automotive industry extended the scope of this kind of system.

Today, car rear lights consist of a few drivers for the light sources that are locally controlled by a light controller, which is usually placed closely to these drivers. The light controller communicates by a CAN or LIN network with the domain controller responsible for lighting e.g. the body domain controller. This is shown in figure 1.

The light control part of the body domain controller consists among others of a micro-controller (e.g. 32-bit MCU), CAN/LIN transceivers, smart high-side drivers to control the power supply of the light module, and its associated power-management device. The light module embeds a small micro-controller for generating the light patterns and to communicate with the body domain controller, DC/DC-convertors to generate the voltages needed for the light sources (LEDs), a simple communication interface like e.g. I<sup>2</sup>C and a power-management device for supply. The light sources are switched by high-side or low-side driver circuits.

Newer and future rear lights show dynamic light patterns that can be used for safety like warning the driver in the car behind of upcoming traffic hazards or for enhancing the design of a car for individualization or branding. Light is a very appealing design element for vehicles. For these uses of light, several hundreds of individual light sources must be controlled, each with its own intensity resolution of at least eight bits at a refresh rate in the range of several milliseconds. Since the light sources are now distributed over the rear of the car, the light module cannot be placed next to the drivers anymore. This means that a reliable and safe communication is needed that provides a high bandwidth at a high level of immunity against the distortions faced in the harsh environment of a car.

Since the light module cannot be placed anymore close to the drivers, a valid question to ask is: Why not using the body domain controller directly for controlling the light drivers? This change in the architecture can be seen in figure 2.

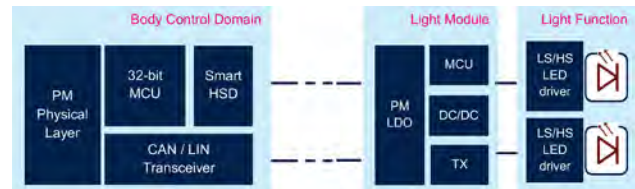


Figure 1: Classic light control (Source: STMicroelectronics)

With a new robust and reliable network, the embedded light module can be spared, and its tasks be taken over by the powerful body domain controller. This not only enhances the functionality of the rear light, but also reduces the system cost and enables easier updates using wireless technologies (“Over-the-air”). Inside the light functions remain only the drivers that communicate directly with the domain controller without the need for any software.

When looking beyond the needs for rear light the same architectures can be seen in other areas of the car. Figure 3 shows the evolution from the flat network architecture towards the domain and zone architectures. Besides the various domain and zonal controllers that are interconnected by high bandwidth networks like Ethernet “clouds” of sensors and actuators exist, that are connected to these controllers. This is very similar to the described rear light network, which makes a lightweight CAN FD network applicable in various sections of the car.

## System costs

A network for communication between a controller and many small devices like actuators and sensors must be reliable and cost efficient. The network protocol must be embedded in these devices without the use of a micro-controller and software. Also, external costly components must be spared. One of the most expensive components in a communication system, is the crystal for generating

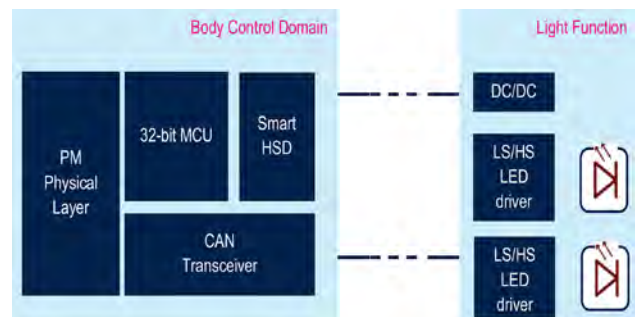


Figure 2: Future light system (Source: STMicroelectronics)

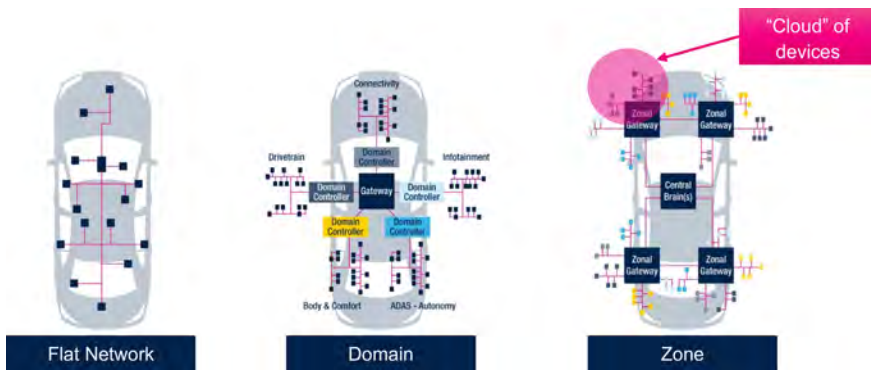


Figure 3: Car network evolution (Source: STMicroelectronics)

the accurate clock frequency to sample the received data-frame and to generate the frame to be transmitted. This crystal cannot be placed at each small communicating device since it would increase the system cost drastically.

Besides the reliability and cost constraints, a network used in the car must not require a new infrastructure at the car makers. It must build on existing tools, software, measurement, and development equipment already available at the development, manufacturing, and service sites. In addition, the transceivers used for this network must already be proven to operate in the automotive environment.

### Why CAN FD?

While new driver and sensor devices with a new communication protocol can be developed within the

regular product upgrade cycle, the hardware inside of the domain controller cannot so easily be changed. Therefore, the network must be able to work with the existing network support the micro-controllers already provide.

While taking all these considerations into account the choice was made to implement a network based on the well-known and widely used CAN FD.

CAN FD provides a bandwidth of 1 Mbit/s, which is more than sufficient for small sensor and actuator networks including dynamic rear light applications. As shown in figure 4, a CAN FD frame provides a data-size of 64 bits per frame with minor control bit overhead. An eleven-bit field for frame identification and, with the inherent bit-stuffing rule a guaranteed edge density for synchronization.

As bus network it is cost-efficient and with one frame, data to several devices can be sent. The frame is protected by a cyclic-redundancy-check (CRC), that has proven its reliability for years in many applications and products.

Hardware protocol controllers inside of existing micro-controllers are on the market, so the domain controllers are not burdened with software running on their cores to realize the network protocol. And, since CAN FD is widely used in the industry, experience and a large tooling environment

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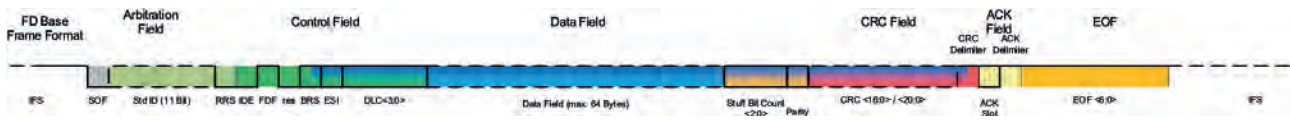


Figure 4: CAN FD base frame format (Source: STMicroelectronics)

including software exist in development, manufacturing, and service areas.

CAN FD is a very flexible network and offers features that are not necessarily needed for communication with small devices. The access to the network is determined by priority which is encoded in the identifier of the frame. Also, errors detected by one network participant are advertised to the entire network by error frames. These features, require due to their synchronization needs an accurate clock that is usually generated using crystals or ceramic resonators, which are as automotive grade quite costly. By replacing these features the crystal and buffer memory, which is necessary in case arbitration is lost, can be removed.

### CAN FD Light

The resulting network is a lightweight CAN FD Light network in which the controller, e.g. the domain or zone controller, controls the entire communication. It sends data to the devices on the network and requests data from them. Only one device answers to such a request. With this strict communication flow arbitration is not needed anymore and since the data flow is clearly identified error frames for advertising errors are not required. The data flow is unidirectional in case the controller sends a dedicated frame to one device and the addressed device is the only one to answer to this frame. The controller is a device with an accurate clock, and it is the only device putting a frame on the network, which excludes phase and frequency shifts introduced by the arbitration. Therefore, the small sensor and actuator devices can synchronize to the controller while receiving the frame. The edge density needed is guaranteed by the CAN FD bit-stuffing rule. This communication scheme ensures the identification of sender and receiver on the network. Communication interrupts can be clearly identified, and error frames are not necessary.

Because the CAN FD network is a bus network broad- and multicast frames sent by the controller to all or several devices are possible, but no answer is expected. A very high network utilization of up to 100 % is feasible because no bandwidth must be reserved to allow unexpected higher priority frames accessing the network. The entire communication flow is deterministic.

Further simplifications to the CAN FD protocol are the restriction to the standard eleven-bit identifier, sticking to the CAN FD format (i.e. no Classical CAN format), and using the same data-rate for the data-phase as for the rest of the frame. As a result, the bits controlling these features are set to fixed values. Sending an acknowledge is not required, but some CAN FD protocol controllers may need it, so they do not transmit error frames.

With these modifications and simplifications, a lightweight protocol controller can be implemented entirely in hardware in small devices without the need for costly external components such as crystals.

### Summary

The transceiver is a standardized Classical CAN, CAN FD, or CAN SIC (signal improvement circuitry) transceiver depending on the used data-rate and the network properties. In summary, this lightweight CAN FD Light provides a high bit-rate of up to 1 Mbit/s or even beyond with a very high network-utilization at a competitive cost. On the controller side, existing hardware protocol controllers for CAN FD can be used while at the driver device side a fully monolithic hardware solution without expensive external components is integrated.

Network reliability is assured by the deterministic unidirectional communication scheme and the frame integrity protection features already implemented in CAN FD like the cyclic redundancy check (CRC). The network topology allows broad- and multicast frames to further enhance the network utilization. The deterministic communication protocol allows on the controller and on the driver device side the reaction of expected but missed frames to inform the driver and to enter a safe state.

With these features and the cost-efficient system implementation many applications for this network exist inside the car, but also in other fields like industrial or building automation. Currently, CAN in Automation (CiA) is working on a [standardization of this lightweight protocol](#) in a special interest group. ◀



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June 14, 2021	
<b>Session I: Physical layer</b>	
<b>Chairperson: Carsten Schanze (VW)</b>	
Magnus-Maria Hell (Infineon)	The physical layer in the CAN XL world
Patrick Isensee (C&S Group)	The challenge of future 10-Mbit/s in-vehicle networks
Johnnie Hancock (Keysight)	Characterizing the physical layer of CAN FD
Chat rooms with speakers, in parallel: CiA CAN Coffee (C <sup>3</sup> )	
<b>Session II: CAN XL data link layer</b>	
<b>Chairperson: Reiner Zitzmann (CiA)</b>	
Florian Hartwich (Robert Bosch)	Introducing CAN XL into CAN networks
Dr. Arthur Mutter (Robert Bosch)	CAN XL error detection capabilities
Dr. Christian Senger (University of Stuttgart)	CRC error detection for CAN XL

June 15, 2021	
<b>Keynote session</b>	
<b>Chairperson: Holger Zeltwanger (CiA)</b>	
Carsten Schanze (VW)	Future of CAN from the perspective of an OEM
<b>Session III: CANopen testing</b>	
<b>Chairperson: Uwe Koppe (Microcontrol)</b>	
Mark Schwager (Vector)	A new approach for simulating and testing of CANopen devices
Oskar Kaplun (CiA)	CANopen FD conformance testing – today and tomorrow
<b>Session IV: CANopen FD</b>	
<b>Chairperson: Christian Schlegel</b>	
Uwe Wilhelm (Peak), Christian Keydel (Emsa)	A simplified classic CANopen-to-CANopen FD migration path using smart bridges
Alexander Philipp (Emolas)	A theoretical approach for node-ID negotiation in CANopen networks
Yao Yao (CiA)	CANopen FD devices identification via new layer setting services (LSS)
Chat rooms with speakers, in parallel: CiA CAN Coffee (C <sup>3</sup> )	

## Program of the 17<sup>th</sup> international CAN Conference

June 16, 2021	
<b>Session V: CAN FD lower layers</b>	
<b>Chairperson: Dr. Frank Deicke (Fraunhofer IPMS)</b>	
Tony Adamson, Axel Engelhard (NXP)	CAN signal improvement and designing 5-Mbit/s networks
Fred Rennig (ST Microelectronics)	A lightweight communication bus based on CAN FD for data exchange with small monolithic actuators and sensors
Kent Lennartsson (Kvaser)	Improved CAN-driver
<b>Session VI: Engineering</b>	
<b>Chairperson: Kent Lennartsson (Kvaser)</b>	
Nikos Zervas (Cast)	Designing a CAN-to-TSN Ethernet gateway
Dr. Heikki Saha (TKE)	Automated workflow for generation of CANopen system monitoring graphical user interface (GUI)
Dr. Christopher Quigley (Warwick)	Benchmarking of CAN systems using the physical layer – car, truck, and, marine case studies
Chat rooms with speakers, in parallel: CiA CAN Coffee (C <sup>3</sup> )	

June 17, 2021	
<b>Session VII: Security</b>	
<b>Chairperson: Torsten Gedenk (Emotas)</b>	
Thilo Schumann (CiA)	Embedded security recap
Prof. Dr. Axel Sikora (Hochschule Offenburg), Georg Olma (NXP), Olaf Pfeiffer (Emsa)	Achieving multi-level CAN (FD) security by complementing available technologies
Donjete Elshani, Vivin Richards (Infineon)	CAN XL made secure
<b>Session VIII: CAN XL higher layers</b>	
<b>Chairperson: Dr. Arthur Mutter (Robert Bosch)</b>	
Peter Decker (Vector)	IP concepts on CAN XL
Christian Schlegel	Multi-PDU concept for heterogeneous backbone networks
Holger Zeltwanger (CiA)	Standardized layer-management options for CAN-based networks
Chat rooms with speakers, in parallel: CiA CAN Coffee (C <sup>3</sup> )	

For details on the 17<sup>th</sup> iCC, please contact CiA office:  
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# Facts & Figures

## More than 700

CAN in Automation (CiA) started with 708 members into 2021. Most of them are device manufacturers (400). Others are

technology enablers (73), tool suppliers (27), and service providers (82). There are also 73 original equipment manufacturers from different application fields. The nonprofit association comprises 18 research entities and 17 software houses.



CiA decided to organize the 17<sup>th</sup> International CAN Conference (iCC) as an online event. It will take place on June 14 to June 17 (four half-days). The reviewed conference agenda and more information on the supporting program can be found on [CiA's website](#).



## 1432

CANopen vendor-IDs have been assigned since 1999. Last year, CiA issued 42 vendor-IDs to members

and 19 to non-members. The annual average is 68 CANopen vendor-IDs assignments.

## CiA webinars

The nonprofit association has scheduled free-of-charge 60-min webinars to several topics.

The webinar list is available on the [CiA website](#). Webinar languages are English, Chinese, and Russian.

End of February 1986, Bosch presented on an SAE congress in Detroit for the first time the CAN serial network to the public. Two years later, Intel in-

troduced the 82526 CAN stand-alone controller followed shortly by Philips Semiconductor offering another 82C200 CAN stand-alone chip.

## 35<sup>th</sup> anniversary

## 30 years ago

In 1991, the first car with a CAN in-vehicle network appeared on the roads. It was the W140 S-Class model by [Mercedes-Benz](#). It was unveiled the W140 S-Class at Geneva Motor Show in March 1991 with sales launch in April 1991 and North American launch in August 1991. The German carmaker produced more than 430 000 of this model.







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# CANopen in the food and beverage industry

*Nord Drivesystems provides corrosion-protected solutions for the food and beverage industry without stainless steel. In those systems CANopen frequency inverters are used.*



(Source: Adobe Stock)

In the food industry, plant and machinery as well as the drive technology that is used must be protected against dirt, moisture, spray water, and aggressive media. However, painted systems are prone to even minor damage and do not offer permanent protection. Drive units made from stainless steel are relatively expensive. The NSD Tuph corrosion protection treatment from Nord is an alternative for aluminum drive housings that considerably prolongs the service life of the installed components in harsh environments. The surface protection can be combined with flexible modular drive products. The drive solutions are available in several sizes as worm gear, parallel gear, parallel shaft-gear or bevel gear units, completely available with a smooth motor and respective drive electronics.

As the drives' surfaces are exposed to scratches and impacts in industrial environments, even high-quality anti-corrosion coatings do not provide effective protection. Once the surface has been damaged, it is often infiltrated by corrosion and also repairs do not permanently help. According to Nord, with their treatment, the surface is more

robust than a paint coating, and slight impairment remains limited to the damaged area. The NSD Tuph drives are not only suitable for hygienically sensitive applications in the food sector but also for various applications in process and pharmaceutical industries. They are typically used on conveyor belts, pumps, mixers or agitators, but also in water and sewage plants, and car wash facilities.

## Food and beverage industry

Reliable drive solutions are an essential requirement for the entire value creation chain throughout the food and beverage industry. From storing, conveying, and processing of raw materials to process engineering and filling right up to packaging and logistics – drive systems tailored to the specific application are required. They need to balance hygiene requirements, technological requirements, and energy efficiency with product protection and demanding environmental conditions such as heat, cold, or moisture in an economical way. Nord Drivesystems, designs complete ▷



Figure 1 + 2: The NSD Tuph surface treatment provides corrosion protection for drive components in wash-down-optimized cast aluminum housings for the food and beverage industry (Source: Nord Drivesystems)



systems consisting of geared motors, frequency inverters, and software. A range of these frequency inverters use CANopen as communication protocol.

### CANopen control cabinet inverters

The control cabinet inverters have a power range of up to 160 kW and can be adapted to customer applications. One of the latest frequency inverters of the company is the Nordac Pro SK 500P. It covers rated motor powers from 0,25 kW to 5,5 kW. Various device versions can be allocated to various application requirements. The inverter features Bluetooth and an SD memory card as a storage medium for parameters and operating data, as well as an USB interface, which enables parameterization of the inverter

when the power is switched off. As mentioned, it also provides a CANopen interface, supporting CiA 402 device profile for drives and motion control. The product can perform up to four gearmotor axis sequentially with positioning functions by reading the encoders of all four axis. Other features are an integrated PLC (programmable logic controller) for motor-related motion and logic control, a 200-% overload reserve for torque and speed performance, as well as sensorless current vector control for asynchronous and synchronous motors (open loop and closed loop). The integrated brake chopper for four-quadrant operation is a part of the basic equipment for the entire series, so is the motor brake management, which is important, e.g. for lifting gear applications. Nord supplies the inverters with integrated STO and SS1. The integrated PLC processes the ▶

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Figure 3: The control cabinet inverters Nordac Pro SK 500P come with CANopen as communication interface (Source: Nord Drivesystems)

data from sensors and actuators and can autonomously initiate control sequences, as well as communicating drive and application data to a control center, networked components, or to cloud storage. This allows continuous condition monitoring and therefore forms the basis for predictive maintenance concepts as well as optimum plant dimensioning. This series is compatible with the SK 500E series.

The Nordac PRO SK 500E is customizable to drive applications. Its functionality can be extended with numerous plug-in option modules. For this inverter, various cooling concepts can be used to remove heat from the control cabinet and can be adapted to the requirements of the application with various option modules. Besides others, it provides CANopen (CiA 301 and CiA 402) as communication interface. CiA 301 is the CANopen application layer and communication profile.

### CANopen and Devicenet decentralized inverters

The company's decentralized inverters can be freely configured and adapted to applications. All of the following-mentioned products come with CANopen and Devicenet as communication interfaces. The Nordac Link SK 250E is a drive solution for field installations near gearmotor. Depending on the application and the requirements, it can be freely customized, which results in a large number of different potential applications for this product. Plug and play capability is provided. Commissioning and servicing of the system is performed with the integrated maintenance switch and the local manual control. The product can be integrated into common control systems via fieldbus or Industrial Ethernet.

The company explained, that the Nordac Flex SK 200E is their most flexible inverter that can be tailored to any customer application by means of mountable functions. Installing and servicing the inverter can be carried out because of its plug-in capability and the parameter transfer via EEPROM memory.

The Nordac Base SK 180E is the Nord's economical drive solution for the decentralized frequency inverter technology sector. The drive with a rugged design was specially developed for simple, cost effective solutions mounted outside the control cabinet.

### Pump drives

Additionally, the company supplies pump drives with special functions tailored to the pumping medium such as

high-starting torques or soft start. Wall or motor-mounted frequency inverters facilitate decentralized automation concepts and mobile pumps with control concepts. For this purpose, again the above-mentioned CANopen and Devicenet decentralized inverters are used.

In combination with the NSD Tugh surface treatment, surface motors, and two-stage bevel gear unit based drives are created that combine light weight and efficiency in various variants with corrosion protection and hygienic surfaces that are easy to clean, explained the company. Even without a fan, they are achieving a considerably better heat dissipation than stainless steel drives while still featuring a similar corrosion protection, the company added. These properties are also required for drives in machines and systems for cutting and dosing as well as in CIP (cleaning-in-place) and SIP (sterilization-in-place) areas. The drive solutions can be designed for extreme application conditions in cooking and baking lines or deep-freeze systems.

### Baking industry

For processing steps such as agitating, mixing, or kneading, Nord is also building gear motors in all sizes with resilient output shaft bearings for high loads. For this application area, the Maxxdrive industrial gear units with output torques from 15 kNm to 282 kNm are suitable. The company provides application-specific equipment options designed for pumps, agitators, and mixers with high process-related radial and axial bearing loads.

### Conveying, filling, and packaging

Synchronous motors with frequency inverter and encoder feedback via absolute or incremental encoders enable positioning applications and movement of small and large packaging units. Nord implements solutions for horizontal, vertical, and inclined conveyors as well as palletizing systems, as well as customized drives for filling systems. With the frequency inverters, soft start, braking ramp, braking, and STO functions can be implemented. Multi-encoder operation, during which a frequency inverter can control up to four motors with encoders, is also possible. For intralogistic systems, the company also offers the Logidrive concept: a modular system for individual, economical drive concepts that achieve a balance between energy efficiency and reduction of variants. The Nordac Link frequency inverter with CANopen and Devicenet is also used in the Logidrive concept. ◀



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## CAN Newsletter Online

In the CAN Newsletter Online CiA reports about CANopen-capable drive and motion controlling systems as soon as they are introduced. Nord Drivesystems and further manufacturers provide frequency inverters with similar functionality:



0,25 kW to 160 kW

### **Frequency inverters with CANopen interface**

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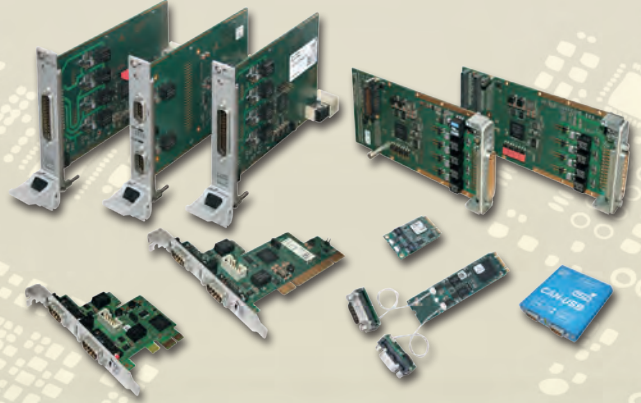
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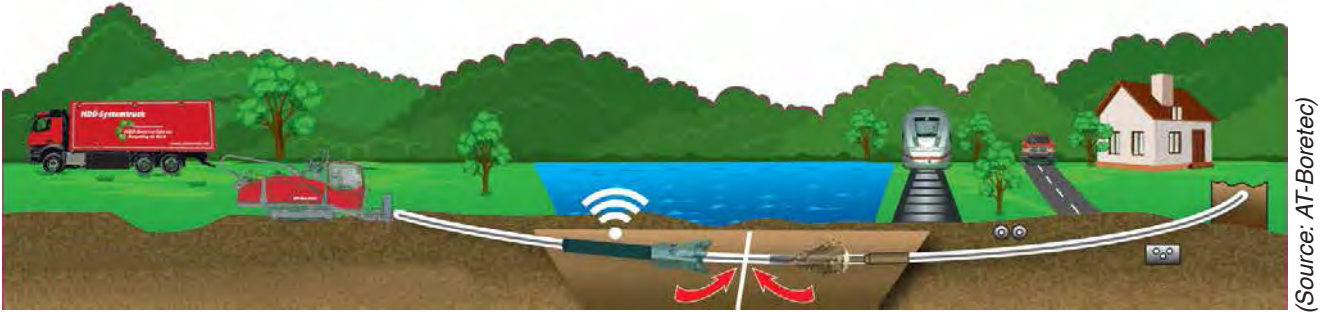
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# Faster drilling for faster Internet

*Absolute CANopen encoders from Wachendorff provide position data in AT-Boretec's horizontal drill machines with automatic pipe feeding.*



(Source: AT-Boretec)

In the scope of the area-wide expansion of mainly rural regions with glass fiber cables, underground works are a common sight in residential areas and along through-roads. To ensure that investments in high-speed broadband communications are not exceeding the budget estimates of the municipalities in road maintenance, underground construction companies mainly use horizontal drills. AT-Boretec from Schmallenberg (Germany) is one of the leading manufacturers of these mobile machines in Europe. In the current series, the Sauerland company is relying on automated feeding of drill pipes from a magazine. Wachendorff Automation has designed the robust encoder for positioning the gripper unit in a manner suitable for use on the construction site.

Distances of up to 500 m are not uncommon with the so-called horizontal flush drilling method. Especially in light soils, pipes and lines can be laid in the ground quickly and effectively with the horizontal directional drilling. Whether wastewater or glass fiber: Horizontal drilling technology has established itself in Germany over the past 20 years and is used especially for sealed surface environments. Powerdrill for soils and Rockdrill for rocks are the names of the two machine series from AT-Boretec. They are scaled in their performance to provide suitable working conditions for different pipe diameters, distances, and radii.

## Precise cable laying

Instead of digging long trenches, AT-Boretec's systems first drive the pilot sewer from one excavation pit to the next with a simultaneous drilling and flushing process. Once the

operator has hit the target, the drill head is replaced by a reamer, which in turn is connected to an empty pipe. When pulling back, the reamer expands the drilling section and simultaneously pulls in the pipe. These two work steps are usually sufficient for laying fiber optic cables. If pipes with larger cross-sections have to be laid, the second work step must be repeated and the drill channel enlarged in stages. For this purpose, various reamers with increasing drill diameters are then used. The general procedure remains the same - also with regard to the use of an emulsion of water and bentonite. The natural aggregate in the water lubricates the drill head, ensures that the removal of sediment can flow out of the bore channel and stabilizes the wall of the bore. The clay-based fluid is prepared on site in the mixing station on a truck and then pumped through the drill pipe to the drill head by a high-pressure pump on board the drill rig. Here the bentonite emerges through nozzles.

## Automatic reloading of drill pipes

The pipe sections that the self-propelled drilling rigs carry in a magazine are between three to four and a half meters long. Depending on the model, 40 to 70 drill pipes can be stored. These are automatically removed by a hydraulically driven removal unit and bolted to the drill pipe. Longer pipe sections are recommended for long distances, as the drilling process does not have to be interrupted as often. When the drill pipe is extended, a gripper unit removes a pipe from the magazine, which is then bolted to the drill pipe in the ground by the drilling carriage. ▶



Figure 1: Horizontal drills from AT-Boretec use the WDGA CANopen encoder from Wachendorff for accurate drilling and automated reloading of the drill pipes (Source: Wachendorff)

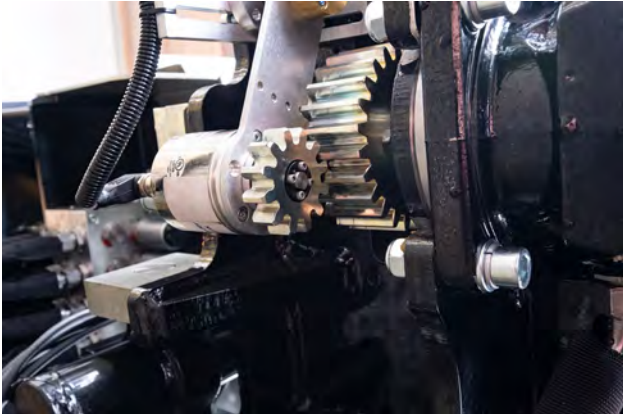


Figure 2: The encoder was fitted with specially adapted bearings and is installed without any protective enclosure; it provides the controller with the necessary data for positioning the removal unit of the drill pipe (Source: Wachendorff)

In previous machine generations, the operator had to manually unlock one magazine row after the other. In the current Powerdrill series, however, the row can be pre-selected via a touch display in the machine cabin. Removal then takes place automatically.

To ensure that the gripper unit knows how far it has to travel, a multi-turn WDGA encoder from Wachendorff Automation passes on the necessary position data to the controller via electrically-isolated CANopen communication. The encoder operates magnetically and is parameterized for a resolution of 18 bit in multi-turn operation. Implementing the company's patented Endra and Quattromag technologies it is wear- and maintenance-free as no gearbox and battery is used. Beside the base CANopen communication services (CiA 301), the encoder supports the CANopen device profile for encoders (CiA 406 version 3.2, class C2). A bi-color status LED indicates the operating conditions and errors according to the CiA 303-3 recommendation. Data exchange at bit-rates of up to 1 Mbit/s is possible.

Comfort for the operator and a machine that has an efficient performance when drilling are the offered advantages of the current AT-Borettec machine series. A Bluetooth interface in the operator's cab, a heating system for the cold season, and air conditioning in summer are provided. Automatic loading of the drill pipe also unburdens the operator, as they can remain seated in the cab and stay dry in the bad weather.

## Heavy-duty encoder

Heavy-duty equipment is necessary to ensure the operational reliability and long service life of the encoder in this demanding application. "Construction site environments are one of the worst things that can happen to a sensor - even in such an exposed position" said Benjamin Ochsendorf, sales engineer at Wachendorff. The Wachendorff encoder is freely mounted under the pipe magazine and is directly exposed to the mud and moisture. For this reason, AT-Borettec was looking for a robust technology when selecting the sensor.

The WDGA multi-turn encoders have a protection class of IP67 (dust-tight, immersion up to 1 m depth) and can operate with a resolution of up to 43 bit (multi-turn) and up to



Figure 3: A status LED is integrated in the encoder housing and allows for a rapid diagnosis in the event of an error (Source: Wachendorff)

16 bit (single-turn). For use in horizontal drills, the shock- (5 000 m/s<sup>2</sup>) and vibration-resistant (300 m/s<sup>2</sup>) encoders are equipped with special bearings. They can support loads of 120 N axially and 220 N radially. Optionally, radial and axial bearing loads of up to 500 N each are also possible. In order not to transfer unnecessary forces to the sensor's axis of rotation, the AT-Borettec encoder is mechanically decoupled by a spring-toothed wheel construction. With a view to operational safety and fast diagnosis in case of error, a status LED is also integrated in the encoder housing. The used encoder has two M12 connectors enabling a flexible and mechanically robust integration into the CAN network. Additional adapters are not required. The necessary bus termination can also be integrated into the encoder if required.

## Conclusion

Thanks to the robust design of the sensor, it is possible to use the WDGA encoder for the positioning system in AT-Borettec construction machines without further enclosures. The IP67-protection, coupled with constructive modifications, ensures that sludge and drilling fluids do not impair the reliable functioning of the encoder. ◀



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# CANopen object dictionary of an injector

This article describes the functionality and the possible relationships of the CANopen objects specified for injectors in CiA 425-2.

The object dictionary (OD) implemented on a CANopen-connected injector is a list of objects existing at run-time and accessible by a scanner via the CANopen network. Each object serves a specific purpose. The OD as a whole defines the injector's application functionality. It determines the injector's operation aspects e.g., features, capabilities, communication parameters, injection protocol parameters, and expected behaviors in case of communication loss. The scanner, which controls the injector, learns those aspects by reading the objects from the injector's OD. The scanner can also influence the injector's behavior by writing new values to the objects, if allowed by the injector. An object can provide a "read-only" (ro), "write-only" (wo), or "read-and-write" (rw) access. An injector may restrict the object's access permission based on its own control measures or safety requirements.

An object in the OD can be one of the two object types: simple and complex. A simple object (variable), contains a single data piece with the data-type (Boolean, Unsigned8, etc.) as specified in CiA 301. A complex object (array or record) contains multiple pieces of data. These pieces may have the same data type (array) or different data-types (record). Each object in the OD is addressed with a 16-bit index and an 8-bit sub-index (00<sub>h</sub> for variables; 00<sub>h</sub> to FE<sub>h</sub> for arrays or records). Each object can be accessed by a scanner using the SDO (service data object) service.

As mentioned above, the OD exists only at the run-time. Once the injector starts up, its OD, with all objects populated with default values, becomes accessible to the scanner. As some of the objects (e.g. 1016<sub>h</sub>, 6070<sub>h</sub>) have invalid default values, the scanner has to configure them via SDO. When the injector shuts down, all object values (including the configured) are lost, as object 1010<sub>h</sub> (store parameters) may not be supported by the injector. Every time the injector starts up (or resets), the scanner must re-configure certain objects. An electronic data sheet (EDS) is a file that lists all the objects (and their default values) supported by an injector. Using the injector's EDS file, the scanner knows which objects the injector supports, and which objects have to be configured.

The OD is divided into communication profile area (objects 1000<sub>h</sub> to 1FFF<sub>h</sub>, e.g. heartbeat), manufacturer-specific profile area (2000<sub>h</sub> to 5FFF<sub>h</sub>, not specified objects), and standardized profile area (6000<sub>h</sub> to 67FF<sub>h</sub>). The standardized profile area objects in CiA 425-2 specify the common application functionality of an injector (see table 1). The objects of the category "conditional" may have to be implemented depending on the injector compliance class.

Table 1: Standardized profile area objects for injectors (Source: CiA 425-2)

Index	Object Name	Object/Data Type	Category*
<b>Device Identity and Profile Version Objects</b>			
6070 <sub>h</sub>	Scanner identity	RECORD	M
6073 <sub>h</sub>	Profile Version	UNSIGNED32	M
<b>Injector FSA-related Objects</b>			
6000 <sub>h</sub>	Control word	UNSIGNED32	M
6001 <sub>h</sub>	Status word	UNSIGNED32	M
6006 <sub>h</sub>	Communication lost	UNSIGNED8	M
<b>Injector Function Objects</b>			
6007 <sub>h</sub>	Functions supported	UNSIGNED32	M
6008 <sub>h</sub>	Global attributes support	ARRAY	M
<b>Injector Capability Objects</b>			
6002 <sub>h</sub>	Injection mode	UNSIGNED8	M
600D <sub>h</sub>	Maximum configurable volume	ARRAY	O
601A <sub>h</sub>	Maximum configurable pressure	UNSIGNED16	O
6028 <sub>h</sub>	Maximum configurable total flow rate	ARRAY	O
6050 <sub>h</sub>	Configured piston content	ARRAY	C
6051 <sub>h</sub>	Injector capabilities	ARRAY	C
<b>Injection Protocol Objects</b>			
6005 <sub>h</sub>	Examination delay	ARRAY	C
6019 <sub>h</sub>	Configured pressure limit	UNSIGNED16	C
6020 <sub>h</sub>	Configured phase type	ARRAY	C
6024 <sub>h</sub>	Configured total flow rate	ARRAY	C
6025 <sub>h</sub>	Configured total volume	ARRAY	C
6027 <sub>h</sub>	Configured delay duration	ARRAY	O
6031 <sub>h</sub> – 6038 <sub>h</sub>	Configured piston ratio 1 – Configured piston ratio 8	ARRAY	C
603E <sub>h</sub>	Configuration check command	UNSIGNED8	reserved
603F <sub>h</sub>	Configuration error list	ARRAY	C
<b>Dynamic Injection Objects</b>			
6009 <sub>h</sub>	Current injected total volume	UNSIGNED16	C
600A <sub>h</sub>	Current pressure	UNSIGNED16	C
600E <sub>h</sub>	Current total flow rate	UNSIGNED16	C
600C <sub>h</sub>	Current volume remaining	ARRAY	C
<b>Achieved Injection Objects</b>			
6021 <sub>h</sub>	Achieved average total flow rate	ARRAY	reserved
6022 <sub>h</sub>	Achieved total volume	ARRAY	C
6023 <sub>h</sub>	Achieved duration	ARRAY	C
6029 <sub>h</sub>	Achieved peak flow rate	ARRAY	C
6039 <sub>h</sub>	Start phase timestamp	ARRAY	O
603A <sub>h</sub>	End phase timestamp	ARRAY	C
<b>Unit and Increment Definition Objects</b>			
6041 <sub>h</sub>	Time unit	UNSIGNED32	C
6042 <sub>h</sub>	Flow rate unit	RECORD	C
6043 <sub>h</sub>	Pressure limit unit	RECORD	C
6044 <sub>h</sub>	Volume unit	RECORD	C
6045 <sub>h</sub>	Piston ratio unit	ARRAY	O
604A <sub>h</sub>	Display increment unit	ARRAY	O

\* M – mandatory; O – optional; C – conditional

## Device identity and profile version

The scanner identity object (6070<sub>h</sub>) includes the scanner's CANopen vendor-ID, product code, revision number, and serial number. After the injector starts up or resets, the scanner has to identify itself to the injector by providing this object with appropriate data. Otherwise, the injector will not communicate with the scanner for security reasons. The injector's identity (same object type as 6070<sub>h</sub>) is specified in object 1018<sub>h</sub>. Upon the injector's startup, the scanner can read this object to determine whether it should provide its own identity to the injector. ▶



Object 6073<sub>h</sub> specifies the CiA 425-1 and CiA 425-2 versions supported by the injector. A scanner reads this object during configuration to interpret the injector objects correctly, as their definitions could have been changed between versions (e.g. 6028<sub>h</sub>).

## Injector FSA-related objects

Object 6000<sub>h</sub> contains the scanner command, which the injector receives via RPDO 1 (receive process data object). Among others, it causes a transition from the current injector FSA (finite state automaton) state to a new state. On a successful state transition, the injector stores a status word (with the new state) in object 6001<sub>h</sub> and transmits the object value to the scanner via TPDO 1 (transmit PDO). If the injector fails to execute the state transition, it sends an emergency message. Then, it sends a copy of the status word still containing the current state. Object 6006<sub>h</sub> specifies whether (and which) state transition an injector will perform in case of communication loss during an injection. The scanner reads this object during configuration, so it knows what to expect when communication loss occurs.

## Injector function objects

Object 6007<sub>h</sub> provides the functions supported by an injector. This 32-bit object currently defines 7 bit (see table 2).

Table 2: Bit field specification of 6007<sub>h</sub> (Source: CiA 425-2)

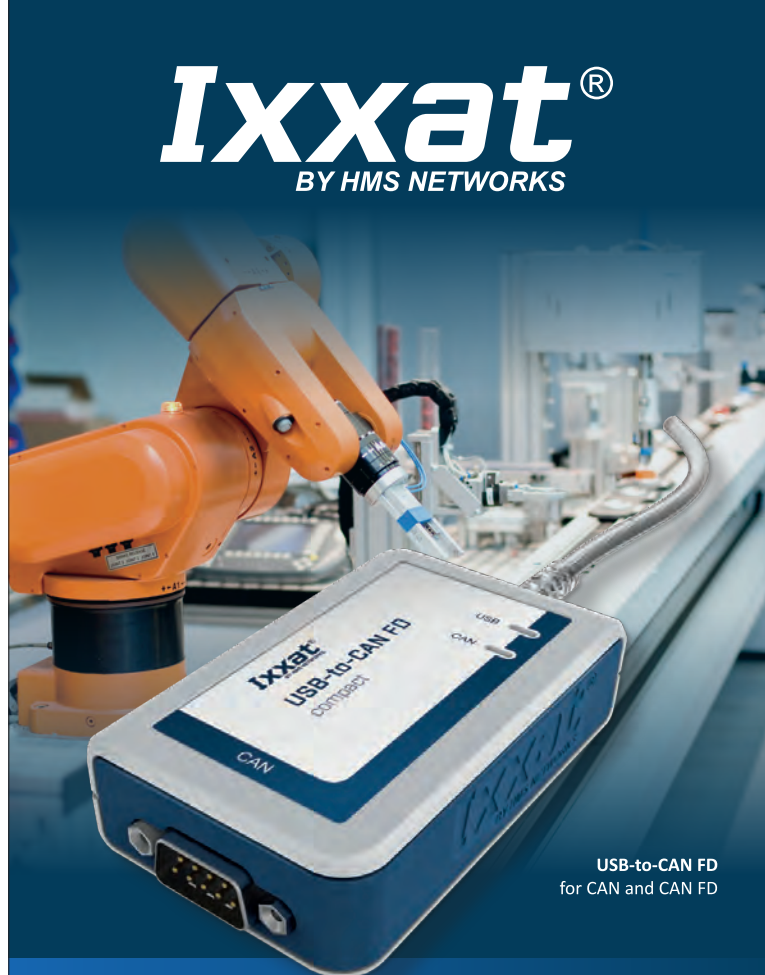
Bit		Description
0	rearm	Whether remote arming (from scanner) is supported
1	reserved	
2	ecg	Whether ECG (electrocardiogram) is supported
3	reserved	
4	skip	Whether "skip forward to phase" command is supported
5	hc	Whether injector state of hold configuration is supported
6	rc	Whether injector state of ready configuration is supported
7	drb <sup>1</sup>	How a delay phase should be handled after hold state
8	mix <sup>2</sup>	Whether mixed flow is supported
9-31	reserved	

Note:

- Bit 7 indicates how an injector handles a remaining delay phase after being put on hold. Assuming that the injector is currently executing a delay phase with a duration of 15 s. When the duration counts down to 5 s, the operator decides to push the hold button (state transition from procedure executing to hold). After a while (not defined how long), the operator ends the hold by pushing the hold-resume button (state transition from hold to procedure executing). What should happen to the remaining 5 s of the delay phase? If bit 7 is set to 0, the injector will terminate the delay phase immediately, and move on to the next phase (if any). If bit 7 is 1, the injector will resume counting down the remaining 5 s.
- Dual-flow is a special and the most common case of the mixed flow, where two syringes are active in an injection phase.

Some injector functions (global attributes) can be controlled remotely by the scanner via the "set global attributes" command (see 6000<sub>h</sub>).

Object 6008<sub>h</sub> is an array with two 16-bit sub-indices (see table 3). Sub-index 1 indicates which global attributes the injector has implemented (bit = 0), meaning that they can be controlled locally by the injector. Since these are ▶



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the injector's implementation details, sub-index 1 has "ro" as access. Sub-index 2 indicates which global attributes (from those implemented by the injector) are further granted permission to be also controlled remotely by the scanner (bit = 1). However, there exist disagreement among the SIG (special interest group) contrast media injector members about which device should grant the permission for the remote control. If it is the injector, sub-index 2 should have the "ro" access type. But if it is the scanner, sub-index 2 should be "rw". In the current version of CiA 425-2, sub-index 2 is "rw". The author thinks that sub-index 2 should be "ro". In other words, the injector should decide which global attributes can be remotely controlled. For example, an injector may support an XDS (extravasation detection system) as an accessory (sub-index 1: bit 3 = 0 i.e. implemented), but it may not allow the scanner to remotely activate it due to the injector's own safety requirements (sub-index 2: bit 3 = 0 i.e. not supported). In such cases, the injector will not delegate the permission to the scanner.

Table 3: Bit field specification of 6008<sub>h</sub> sub-indices (Source: CiA 425-2)

Bit	6000 <sub>h</sub> Global Attribute Bit	
0-2	reserved	
3	11	Activate/stop XDS
4	12	Start/stop KVO (keep veins open)
5	13	Lock/unlock local Arm button
6	14	Lock/unlock local Start button
7	15	Lock/unlock local Hold-Resume button
8	16	Lock/unlock local configuration
9	17	Transition 8* automatic/commanded
10	18	Provide phase number/type
11	22	Provide examination delay status
12	23	Provide injector reconfiguration status
13	19	Provide configuration check status
14-15	reserved	

\* Injection completed to procedure completed

## Injector capability objects

Object 6002<sub>h</sub> indicates what kind of injection an injector can perform, such as CT, CV, or MR injection. In addition, bit 0 indicates whether remote arming is allowed, which requires that the injector supports remote arming (6007<sub>h</sub>: bit 0 = 1, see table 2). Interestingly, this object has the "rw" access permission in the idle state and in any of the configuration states. This implies that a scanner is potentially able to configure this object so that, for example, a CT injector can be turned into an MR injector. This is unlikely to happen. So, this object is usually implemented as "ro" in all injector states.

Object 600D<sub>h</sub> indicates the maximum configurable volume of an injection protocol to use for each fluid type (see 6050<sub>h</sub> below). This is the total capacity of all syringes filled with the same fluid type. Each sub-index of this array represents one syringe (or piston) type. Object 601A<sub>h</sub> indicates the maximum allowed pressure for the syringes installed on the injector. It applies to all injection phases.

Originally, object 6028<sub>h</sub> indicated the maximum configurable total flow rate for each injection protocol phase. For a dual-flow phase, it was the total of the two involved flow rates. Since CiA 425 version 2.2.0 the meaning of this object has changed. Now it means the maximum flow rate

for each syringe (or piston). Therefore, the word "total" in the object's name is no longer appropriate.

Object 6050<sub>h</sub> indicates the fluid type (e.g. contrast media, saline) in each syringe (represented by a sub-index). The highest bit of each sub-index value also indicates whether that syringe is in service. Object 6051<sub>h</sub> (array) indicates the maximum number of possible phases (sub-index 1), the maximum number of injection phases (sub-index 2) and the maximum number of delay phases (sub-index 3, see also 6020<sub>h</sub>).

## Injection protocol objects

The injection protocol configuration objects can only be configured (written to) when the injector is in one of the configuration states. Object 6005<sub>h</sub> specifies an examination delay (sub-index 1), which must be within the minimum value (sub-index 2) and the maximum value (sub-index 3), or 0 (no delay). When an injector enters the procedure executing state, the injection starts. At the same time the examination delay countdown starts as well. In this sense, the examination delay (also called scan delay) has no direct impact on the ongoing injection. However, the injector cannot enter the procedure completed state until the examination delay has counted down to 0.

Object 6019<sub>h</sub> specifies the pressure limit for the current injection protocol, which must be less than or equal to the value of object 601A<sub>h</sub> (maximum configurable pressure). If the pressure during an injection exceeds the value of 6019<sub>h</sub>, the injection may be aborted by the injector.

Object 6020<sub>h</sub> specifies the four phase types for each injection protocol phase: injection (1), delay (2), wait (3), and test bolus (4). The delay phase has a configured duration. The wait phase is infinite until it is terminated by a local action or a remote command that is not part of the injection protocol.

Object 6024<sub>h</sub> specifies the total flow rate for each injection protocol phase. For a dual-flow phase, it is the total of the both involved flow rates. The actual flow rate allocated to each fluid is based on the fluid ratio (see 6031<sub>h</sub> to 6038<sub>h</sub>). Object 6025<sub>h</sub> specifies the total volume for each injection protocol phase. For a dual-flow phase, it is the total of the two volumes of both involved fluids. The actual volume allocated to each fluid is based on the fluid ratio (see 6031<sub>h</sub> to 6038<sub>h</sub>). Object 6027<sub>h</sub> specifies the delay duration for each injection protocol phase. This is meaningful only for a delay phase (see 6020<sub>h</sub>), otherwise it is always 0. Objects 6031<sub>h</sub> to 6038<sub>h</sub> specify the fluid ratio in syringes 1 to 8 for each injection protocol phase. For a single flow phase, a ratio of 100 (in %) must be set for the corresponding syringe. For a dual (or more) flow phase, the total ratio of the two (or more) syringes must be 100 (%). In this case, the specific ratio for each syringe is controlled by object 6045<sub>h</sub> (see unit and increment definition objects).

Previously with object 603E<sub>h</sub>, the injector received (by SDO) the configuration check command from the scanner. If the object value is 1, the injector first clears the configuration errors in object 603F<sub>h</sub> (see below), sets sub-index 0 of 603F<sub>h</sub> to 0, and executes the configuration check. If ▶

the check succeeds, sub-index 0 of 603F<sub>h</sub> is set to 1, and sub-index 1 is set to 0 (no error). But if the check fails, sub-index 0 of 603F<sub>h</sub> is set to the number of errors, and the subsequent sub-indices are filled with the appropriate error codes (e.g. volume too high). If the value of object 603E<sub>h</sub> is 0, only the configuration errors are cleared, no configuration check itself takes place. Since the scanner sends this command via SDO, there is no mechanism for the injector to inform the scanner about the completed configuration check. To find out the check status, the scanner needs to periodically read object 603F<sub>h</sub>, sub-index 0 until it gets a non-zero value. Because of this inefficiency, object 603E<sub>h</sub> has been deprecated since CiA 425-2 version 2.2.0. Instead, a new "execute configuration check" command has been added to the control word 6000<sub>h</sub>. Since the control word is received via RPDO 1, the injector must transmit a status word via TPDO 1 with the result of the configuration check. This is much more efficient.

Object 603F<sub>h</sub> contains a list of pre-defined configuration check error codes that have resulted from the last configuration check command. Before the first configuration check or after a successful one, sub-index 0 is 1, and sub-index 1 is 0 (no error). This is one of the few cases where the value of sub-index 0 is not equal to the highest sub-index number of the object.

### Dynamic injection objects

"Dynamic" means here that the object values are periodically updated by the injector during an injection. The object values are also periodically sent to the scanner via TPDO 2 to TPDO 4 with a rate determined by the scanner. Object 6009<sub>h</sub> provides the total volume (from all active syringes) delivered so far during the current injection. Object 600A<sub>h</sub> provides the pressure that is being measured during the current injection. Object 600B<sub>h</sub> provides the total measured flow rate during the current injection. If the current phase is a dual-flow phase, it is the total of the two flow rates. Values of 6009<sub>h</sub>, 600A<sub>h</sub>, and 600B<sub>h</sub> are sent to the scanner via TPDO 2.

Object 600C<sub>h</sub> provides volumes that are remaining in all active syringes. This array represents a syringe in each sub-index. Values of this object are sent to the scanner via TPDO 3 (sub-indices 1 to 4) and TPDO 4 (sub-indices 5 to 8). If an injector has four or less syringes, TPDO 4 is disabled.

### Achieved injection objects

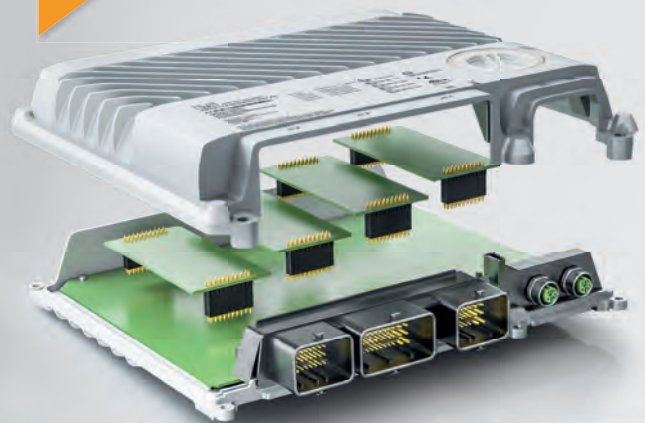
The actually achieved values for each injection phase are placed into these objects right after the phase is completed. The scanner is then notified via the injector status word and can therefore read those values if required. The achieved values are kept until the injector enters the system ready state for the next injection.

Object 6021<sub>h</sub> holds the average total flow rate for each injection phase. For a dual-flow phase, it is the total of the two flow rates. Since it is an average value, the actual phase duration (see 6023<sub>h</sub>) will impact it. For example, if a phase is put on hold for a period of time, the phase duration will become longer. However, CiA 425-2 is silent on ▶



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whether the hold time should be included in calculating the average flow rate for the phase. If the hold time is included, the average value could be well below the configured value, which could confuse the end users. For this reason, CiA 425-2 version 2.2.0 has added object 6029<sub>h</sub> to replace 6021<sub>h</sub>. Object 6029<sub>h</sub> provides the peak (highest) flow rate for each injection phase, which should be very close (if not equal) to the phase's configured flow rate value.

Object 6022<sub>h</sub> holds the total volume for each injection phase. For a dual-flow phase, it is the total of both fluid volumes. Object 6023<sub>h</sub> provides the actual injection duration for each phase. Objects 6039<sub>h</sub> and 603A<sub>h</sub> hold the start and end timestamp for each injection phase, respectively. The difference between the two values should match the actual injection phase duration (6023<sub>h</sub>).

## Unit and increment definition objects

These objects define simple and complex units for the injection parameters. The latter include the unit (sub-index 1), the low limit (sub-index 2) and the high limit (sub-index 3) constraining the unit's value range. A unit is an unsigned32 value with the structure specified in the object 0080<sub>h</sub>, sub-index 1 (see figure 1).

numerator	denominator	prefix	00 <sub>h</sub>
MSB			LSB

Figure 1: Unit value structure (Source: CiA 425-2)

The unit representation is interpreted as: prefix \* numerator/denominator. For units without a denominator (e.g. time), the denominator byte is 00<sub>h</sub>. The full list of codes for the numerator, denominator, and prefix is specified in CiA 303-2[3]. If the LSB (least significant byte) has a non-zero value, the 4-byte unsigned value is interpreted as an increment (see figure 2). An increment specifies a unit's resolution used for input or output purposes. In this case, the unit value is interpreted as: increment \* prefix \* numerator/denominator.

numerator	denominator	prefix	increment
MSB			LSB

Figure 2: Unit value structure with an increment (Source: CiA 425-2)

Object 6041<sub>h</sub> defines the time unit used by objects representing time (e.g. 6005<sub>h</sub>, 6027<sub>h</sub>). Objects 6042<sub>h</sub>, 6043<sub>h</sub> and 6044<sub>h</sub> define the complex units for flow rate, pressure limit, and volume, respectively. These units are used by injection protocol, dynamic injection, and achieved injection objects. The chosen low and high limits must be wide enough to represent all possible values for the corresponding parameters.

Object 6045<sub>h</sub> defines the minimum piston ratio increment and its limits. It applies only to dual-flow (or mixed flow) injection phases. For such phases, each value of objects 6031<sub>h</sub> to 6038<sub>h</sub> must be a multiple of the ratio increment (sub-index 1) and within the defined range (between sub-index 2 and sub-index 3). Furthermore, the total of the mixed-flow values involved in a phase must be 100 (%).

For values of time, volume, pressure, piston ratio and flow rate that are displayed on the injector's user interface, object 604A<sub>h</sub> defines the increments for these parameters. The difference between sub-index 4 of 604A<sub>h</sub> (piston ratio) and sub-index 1 of 6045<sub>h</sub> (scalable increment) is that the former is used for output and the latter for input (configuration) purposes. ◀

## References

- [1] CiA 301: CANopen application layer and communication profile, version 4.2.0, 2011
- [2] CiA 425-2: CANopen application profile for medical diagnostic add-on modules, Part 2: Injector, version 2.3.4, 2017
- [3] CiA 303-2: CANopen recommendation, Part 2: Representation of SI units and prefixes, version 1.5.0, 2012



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# Electric vehicle warning sound system

Analog Devices (AD) developed two solutions that can synthesize in-cabin engine sounds as well as external engine sounds and adjust them on the traveling speed.

Traditional combustion engine vehicles emit engine sound, even at low travel speeds. Typically, pedestrians and other traffic participants recognize an approaching or departing vehicle through sight and auditory identification of tire sounds and other emitted noise when the vehicle is out of sight.

Electric vehicles (EVs) do not emit engine sound. Hybrid electric vehicles (HEVs) or plug-in hybrid electric vehicles (PHEVs) move almost silently when traveling at low speeds and before the conventional internal combustion engine kicks in. These vehicles are difficult to hear when travelling at speeds less than 30 km/h. At greater speeds, the tire sound becomes dominant.

Global governing bodies are exploring legislation that seeks to establish a minimum level of sound for EVs so that visually impaired people, pedestrians, and cyclists can hear these vehicles approach and determine from which direction these vehicles are approaching. An example of this legislation can be found on the National Highway Traffic Safety Administration (NHTSA, United States) website.

An electric vehicle warning sound system (EVWSS) produces a series of sounds designed to alert pedestrians to the presence of EVs, HEVs, and PHEVs. The driver can initiate warning sounds (similar to the sound from a car horn, but less urgent); however, the sounds must automatically be enabled at low speeds. These sounds vary from artificial tones to realistic sounds that mimic engine noise and tires moving over gravel.

Analog Devices offers two different solutions for applications with an in-cabin engine sound and an external engine sound. The advanced engine sound system solution is based on the ADSP-BF706 Blackfin+ processor. For entry-level systems, a solution based on the ADAU1450 SigmaDSP was developed. These solutions can synthesize sound and adjust frequency, sound volume, and other parameters depending on the traveling speed. Then the audio signal is sent to an audio power amplifier. The warning sound can be simulated using combustion engine sounds or any other synthesized tones.

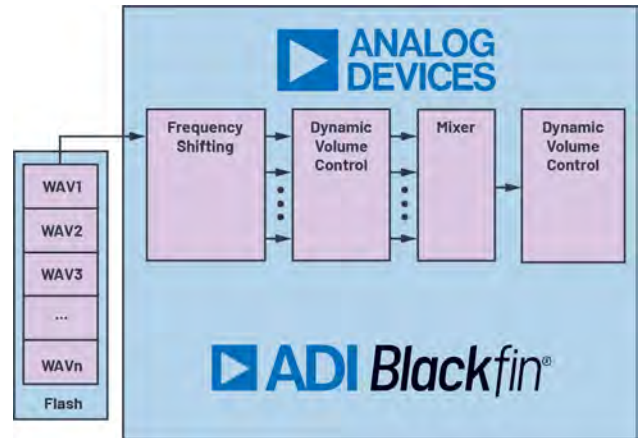


Figure 1: Processing blocks on Blackfin+ processor (Source: AD)

## Blackfin-based solution

The ADSP-BF706 Blackfin+ processor provides a single-chip solution for audio processing and interfacing to the CAN network. AD developed a CAN software stack that runs on the ADSP-BF706, which enables users to build automotive-grade demonstrations using

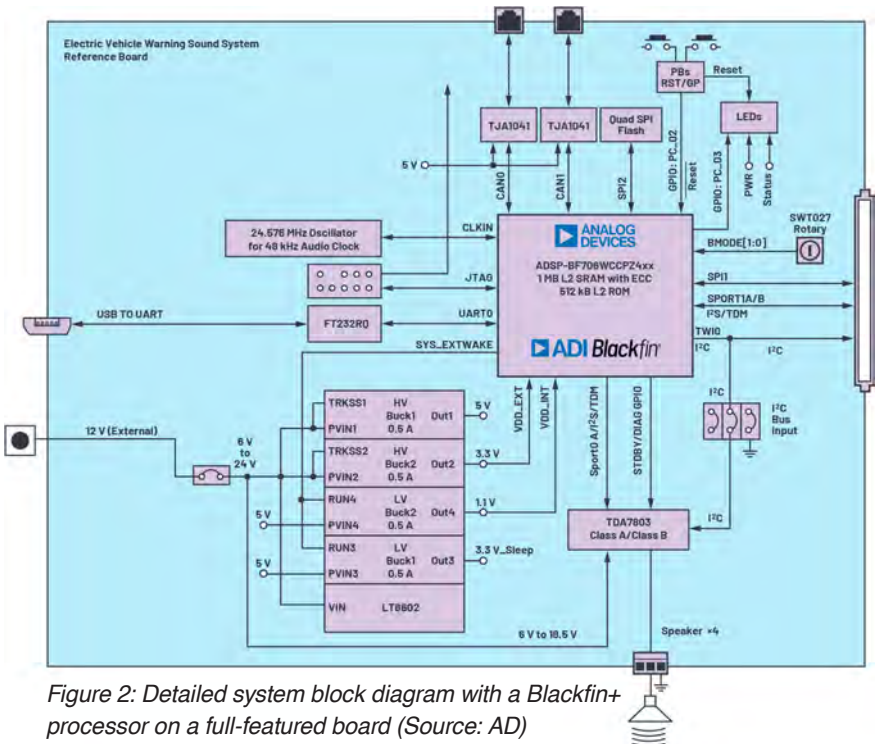


Figure 2: Detailed system block diagram with a Blackfin+ processor on a full-featured board (Source: AD)

## CiA test center

- ▶ CANopen conformance testing
- ▶ CANopen FD conformance testing (new)
- ▶ CiA plugfests



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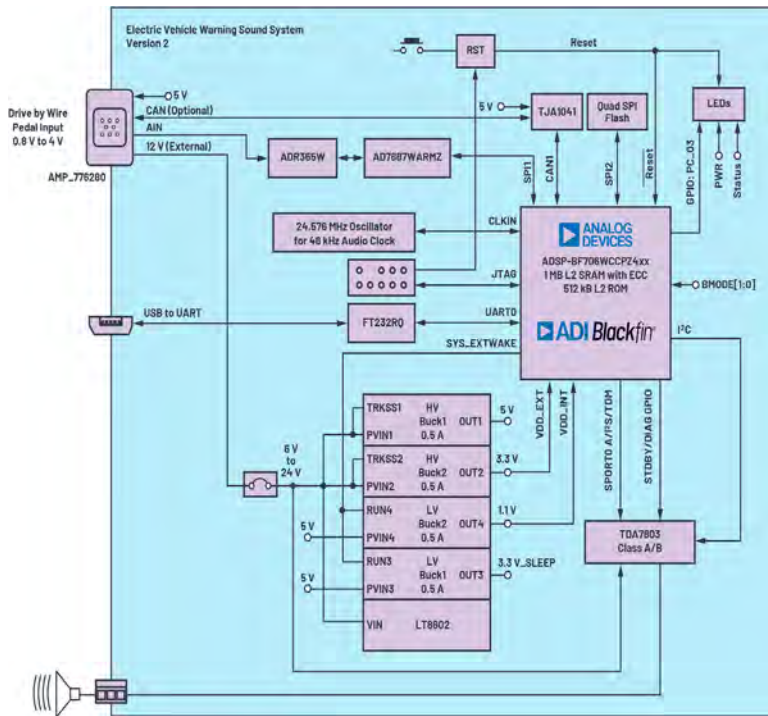


Figure 3: Detailed system block diagram with a Blackfin+ processor on a board with reduced components (Source: AD)

e.g., a CAN stack by Vector. Additionally, AD provides a hardware and software reference design and Sigmastudio compatibility for the live tuning of parameters.

Figure 1 shows the different processing blocks inside the ADSP-BF706. External waveform audio files (WAVs, up to 25) store signature engine sounds or audio tones. These files are frequency-shifted and mixed internally in the digital signal processor (DSP) before adding the dynamic volume control.

The ADSP-BF706 utilizes a memory-mapped SPI (serial peripheral interface) interface that provides access to the external memory, which eliminates the need for an external double data-rate (DDR) memory for this application. Up to 25 WAV files can be accessed simultaneously from the SPI flash memory. The large number of accessible WAV files helps to create more realistic engine sounds.

The ADSP-BF706 can also implement up to 16 pitch shifting variants (recommended from NHTSA), which increases the frequency of the output sound as the vehicle speed increases. The ADSP-BF706 can dynamically control the volume as the vehicle speed increases. The vehicle speed value is provided from the in-vehicle CAN network.

Figure 2 shows a detailed system block diagram. A power-by-linear LT8602 step-down regulator provides all voltage rails required in the system supplied by the 12-V<sub>DC</sub> car battery. The 2-MHz switching frequency allows users to avoid critical, noise-sensitive frequency bands. The 3-V<sub>DC</sub> to 42-V<sub>DC</sub> input voltage makes the LT8602 suitable for automotive applications, which must regulate through cold crank and start/stop scenarios with minimum 3-V<sub>DC</sub> input voltages and load dump transients more than 40 V<sub>DC</sub>.

Figure 3 shows an alternative system block diagram with connectors, a reduced set of peripherals, and one ▶



Figure 4: EVWSS software architecture block diagram (Source: AD)

by AD on request in the software download package.

### Blackfin solution software architecture

The EVWSS software architecture (see figure 4) is based on the ADSP-BF706 processor hardware architecture. The CAN interface reads directly from the flash memory using the memory mapped SPI. This reduces the complexity of the EVWSS library and makes the memory access efficient for warning sound generation.

The Sport callback feature maps to the audio data sample rate and runs in the Sport transceiver interrupt service routine (ISR) context, reading flash files, performing audio manipulation, and sending out modified audio on the Sport transceiver interface. The EVWSS library holds the different functions to synthesize the warning sound. It also receives the vehicle speed input from the CAN stack (or the UART interface for debugging). The TDA7803 driver controls the external power amplifier to generate the warning sound. The EVWSS application framework configures the system peripherals, the CAN stack, and the TDA7803 driver.

In this application, the base pitch (audio signal spectrum) of the WAV file is shifted depending on the vehicle speed input. The engine sound depends on the engine strokes (intake, compression, expansion, and exhaust). These strokes create frequency modulated tones instead

of pure tones. Varying the pitch shift parameters allows to achieve frequency modulation. Two kinds of modulation are included in this application. In the sawtooth modulation, the frequency ramps from the lowest to the highest and then back to the lowest with a jump. In the triangular modulation, the frequency ramps from the lowest to the highest and then ramps back down to the lowest.

The solution details can be seen in the demo manuals, which are provided

of pure tones. Varying the pitch shift parameters allows to achieve frequency modulation. Two kinds of modulation are included in this application. In the sawtooth modulation, the frequency ramps from the lowest to the highest and then back to the lowest with a jump. In the triangular modulation, the frequency ramps from the lowest to the highest and then ramps back down to the lowest.

For audio mixing the various gains can be configured with respect to the vehicle speed. Although the required WAV files are present in the flash, the user can play or stop some of the WAV files, depending on the dynamic conditions.

### SigmaDSP-based solution

For entry-level applications, an ADAU1450 SigmaDSP processor can be used as an alternative to the ADSP-BF706.

ADAU1450 supports the Sigmastudio graphical programming environment for automotive applications. The software features include multiple tone generation, dynamic volume control with up to 64 ranges, sound mixing, limiter function, pitch shifting, and a simultaneous playback of up to five WAV files from the SPI flash memory. The Sigmastudio cannot support a CAN software stack i.e., an external micro-processor is required. Sigmastudio can be downloaded from the company's website.

### Conclusion

Analog Devices offers solutions for an entry-level system and for an advanced engine sound system that supports in-cabin engine sounds and external engine sounds. The solutions include the necessary software components for rapid prototyping and product development. ◀

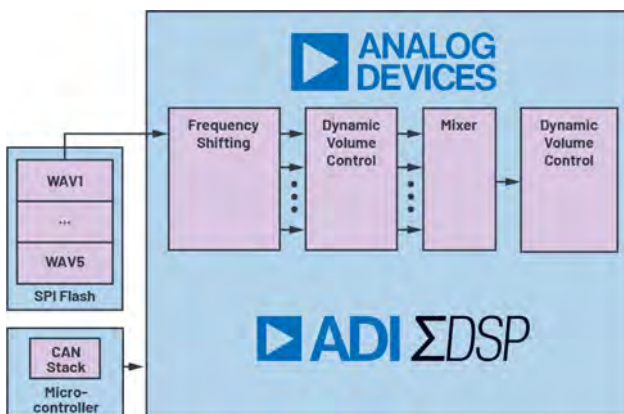


Figure 5: Processing blocks on the SigmaDSP processor (Source: AD)



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# Future of CAN networking in VW's passenger cars

VW has established the Car.Software unit. It is not only responsible for the software development as the name suggests, but also for the in-vehicle networking. CAN is an important communication technology for future VW cars.

CAN was, is, and will be one of the most important communication technologies used in VW's passenger cars. Historically, the Volkswagen (VW) Group was the inventor of the A-Bus, competing against Classical CAN, in the late 80ties. After the automotive industry decided to use jointly the OEM-independent (original equipment manufacturer) CAN protocol, originally developed by Bosch, VW was and is highly committed to CAN, internationally standardized in the ISO 11898 series. VW is even one of the early CAN FD supporters, and initiated the development of the CAN XL protocol, the third CAN protocol generation.

Carsten Schanze from Volkswagen stated in his iCC 2020 keynote ([the conference has been postponed to June 2021, due to the Covid-19 pandemic](#)) that the Golf models are the carriers of new communication technologies: "The Golf was established in 1974 and, until today, more than 35 million vehicles are sold. The requirements for future CAN networks respectively future architectures will be found by looking into the CAN networks of the Golf generations." In the first three Golf generations no CAN network was implemented at all. CAN communication started with the fourth generation of the Golf in 1998 with two CAN networks.

Nowadays, there is the trend to substitute even some [LIN networks](#) by CAN networks. "This change is done due to diagnosis requirements," explained Schanze. "The introduction of Ethernet-based communication technologies, e.g. 100Base-T1, in control units shifts the CAN control units one level down. CAN control units are mainly used as sensor respectively actor control units." Furthermore, security reasons necessitate transmitting

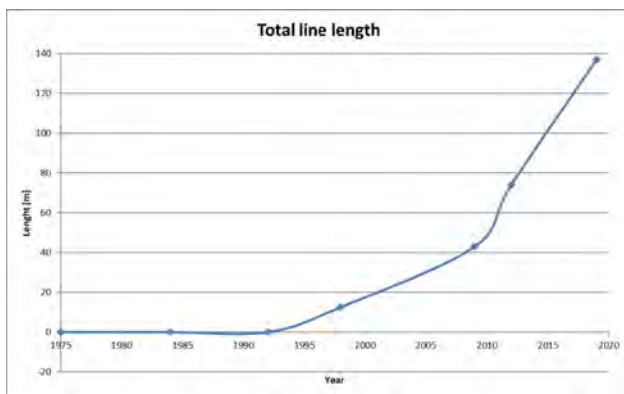


Figure 1: Total network length in Golf cars, which needs to be reduced in future vehicles to save weight (Source: VW)

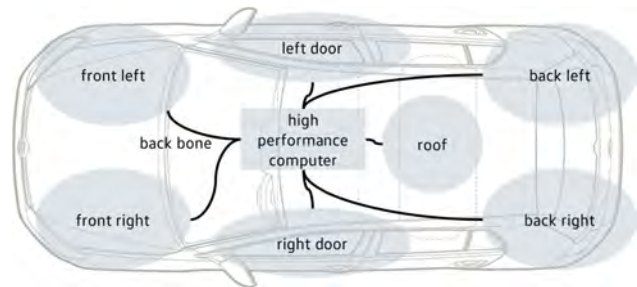


Figure 2: Zone networking architecture example (Source: VW)

a signature for certain ECUs (electronic control units). In order to reduce the effort of generating such a signature, messages are merged, so that just one signature is needed instead of multiple once for shorter messages. This leads to messages with larger data fields. This is, why VW proposed the CAN XL protocol with payloads up to 2 048 byte. Additionally, this allows an easy integration in a TCP/IP-based environment using Ethernet-based networks as backbone between different zone control sub-systems with deeply embedded networks.

Carsten Schanze provided in his iCC paper the following future requirements, deriving from an analysis of the past and present in-vehicle networking:

- ◆ Clean-up of the wiring harness, in order to reduce the weight, to gain space, and to ensure the signal integrity;
- ◆ More scalability, in order to get more bandwidth and to get sufficient payload length.

"The vision for the future is to reduce the different architectures: 'One architecture fits all', stated Schanze. "Zone architectures will solve the first requirement to reduce the weight and gain space for the packaging of control units and the layout of the wire harness. The requirements for the bandwidth are increasing from the sensor/actor level to the high performance computer."

The introduction of zones offers an additional possibility of scaling. As today, the number of ECUs and the bit-rate are scalable. "Furthermore, the number of zones in the car and the communication technology of backbone networks are scalable," Schanze added. "A good approach of a communication technology for such an architecture seems to be CAN XL." The CAN XL protocol offers a data-field that is able to transmit TCP/IP segments. CAN XL-connected ECUs can be used in a multi-drop topology. The bit-rate of the CAN XL communication is scalable until a net bit-rate of more than 10 Mbit/s. CAN XL can run on high-speed ▶



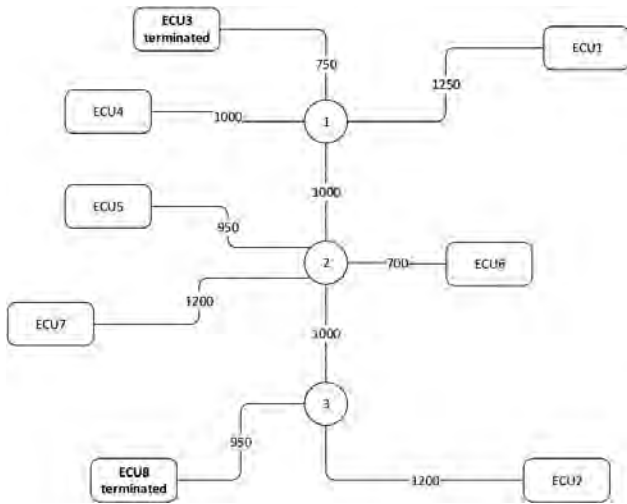


Figure 3: Possible CAN XL topology (Source: VW)

CAN physical interfaces as specified in ISO 11898-2:2016, CAN SIC interfaces as specified in CiA 601-4 as well as CAN XL SIC interfaces as specified in CiA 610-3 (under development). Of course, the CAN XL payload is also scalable from 1 byte to 2 048 byte.

VW plans to use in its next generation of in-vehicle networks CAN FD substituting all legacy Classical CAN networks and CAN XL networks. Carsten Schanze concluded: “The change to zone architectures will straighten the topology to reduce the total line length and thereby the weight.” The needed bandwidth is provided by CAN FD in conjunction with CAN SIC transceivers respectively CAN XL using CAN XL SIC transceivers. The CAN FD (up to 64 byte) and CAN XL (up to 2 048 byte) payloads are larger as the Classical CAN payload (up to 8 byte). Both CAN FD SIC and CAN XL SIC transceivers feature signal improvement capability, so that the settle time after a bit change is reduced.

### Committed to open source approaches

“Open source is becoming increasingly important for software development – and could help Volkswagen make progress on its way from a pure car manufacturer to a car and software provider.” That is Oliver Hartkopp’s mission. ▶



Figure 4: Oliver Hartkopp, VW’s open source missioner and one of the SocketCAN developers: “Technology, strategy, processes – Open Source is a huge topic. My job is to anchor it at Volkswagen.” (Source: VW)

# CiA

CAN in Automation

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## Volkswagen's Car.Software unit

Starting beginning of 2020, the Car.Software organization operates as an in-dependent business unit. As a VW Group company, it centralizes the associates and subsidiaries that develop car software and software for the digital ecosystems. Initially, around 3 000 experts from the software-related associates and subsidiaries are grouped together in this unit. The focus of the Car.



*Dirk Hilgenberg leads the Car.Software organization (Source: VW)*

Software organization is on developing common software for all brands and markets at the VW Group. This is primarily about the VW.OS automotive operating system and the connectivity with the Volkswagen automotive cloud. In addition, the Car.Software organization will consolidate the technological platform solutions for data-driven business models and innovations at the Group. One other task is the development of future in-vehicle network architectures. This includes CAN FD and CAN XL networks.

Investments of more than seven billion euros are planned for these tasks by 2025. The Car.Software unit brings together international expertise. It has its organizational base in Ingolstadt and, with its subsidiaries, has other sites in Germany including in Berlin, Stuttgart, Wolfsburg, and, in the future, Munich. In addition, the Car.Software unit has locations in Europe, as well as in China, the United States, Israel, and India. By 2025, more than 10 000 employees will work in this business unit.

Dirk Hilgenberg manages the Car.Software organization. He graduated in physics. In 1999, he began his career as General Manager Plant IT Operation at BMW UK Manufacturing Ltd. In 2017, Hilgenberg was appointed Senior Vice President Manufacturing Engineering at the BMW Group in Munich. He is now the CEO of the Car.Software unit.

ware used. In 2006, Volkswagen published SocketCAN as open source. By the way, this Linux driver does not only run on the test vehicle on display and in automotive development departments within and outside the VW Group: some fish trawlers on the Atlantic, heavy-duty cranes in the port of Hamburg, the Cern nuclear research facility in Geneva, and a scientific institute in Novosibirsk also use the software, which had its origins in VW Group research.

Since 2008, Oliver Hartkopp is responsible for more than 6 000 lines of code in the Linux kernel – the “core” of the Linux operating system. In addition, the Car.Software unit and the use of open source will make Volkswagen a much more attractive employer for software developers. “If we go from ‘We buy everything’ to ‘We do more ourselves’, we will automatically attract more people who are familiar with software,” said Hartkopp, Volkswagen’s open source preacher. “I also think it’s really exciting about my job that I can be a pioneer in shaping this new culture here at Volkswagen.” He organizes workshops, gives training courses for developers together with the legal department, is often in contact with colleagues from the Group’s brands via Skype conferences, and gives lectures about open source: “I’m kind of a missionary.” He is now part of the new Car. Software organization. ◀

*Holger Zeltwanger*

Oliver Hartkopp is well-known in the CAN community, because he is one of the fathers of the SocketCAN open source Linux software driver. A couple of years ago, he had a lot to do with building prototypes. In order to be able to access the CAN (Controller Area Network) network-based steering solutions, Volkswagen always purchased new systems from new suppliers. For Hartkopp this was incomprehensible. He researched the open source community, consulted with a colleague, and in 2003 began programming an extension for the Linux operating system himself, with which it is now possible to access the CAN network via standardized interfaces – regardless of the CAN hard-

# Migration from Classical CAN to CAN FD

The evolution of Classical CAN to CAN FD and its standardization within ISO 11898-1:2015 has opened the way for CAN FD applications. Especially, raising the performance of entire machine units with as little effort as possible makes CAN FD an interesting option.

Due to its high data security the CAN network has been successfully established in automotive applications and in the industrial automation sector as well as safety-related areas. The longstanding CAN network has not only become a standard in the automotive industry, but has also proven effective in the field of industrial automation, elevator engineering, or medical engineering as well as for vehicle bodies or marine electronics. As a result of growing demands within the automotive sector, in 2011 Bosch initiated the further development of the CAN protocol. In close collaboration with other CAN experts the protocol underwent further development and was equipped with a flexible data rate (FD) enhancement. The low data-rate of 1 Mbit/s with cable lengths of around 40 m as well as limited user data of 8 bit did not comply anymore with the desired performance characteristics of modern CAN applications. The data throughput can be increased by a factor of eight without changing cabling and infrastructure.

Especially, complex electronic controllers require a wider range when it comes to software downloads or servomotor controls. CAN FD allows data-rates up to 10 Mbit/s and transmission up to 64-bit user data. This increased data-range of 64 bit also corresponds to the smallest possible message within the Ethernet protocol. In this way, gateways between CAN FD and Ethernet can be realized more easily. Moreover, related data items can be transferred in a single data package and do not have to be synchronized by software. This makes handling of application programs and system design much easier and more convenient.

The continued simple data link protocol, the cost-effective controller, and transceiver chips with a low power consumption make CAN FD a particularly attractive solution: thanks to its robustness and reliability CAN FD was adopted quite fast in the automotive industry. In this sector CAN FD products are successfully used for test builds and testing systems. Outside of automotive applications CAN FD is applied for example in CAN-based machines and plant equipment. Due to the same CAN frame design the existing cabling can be used. Even for ongoing developments of applications a migration to CAN FD can be accomplished quite easily.



Figure 1: CAN FD boards of 402 series in various form factors (Source: ESD Electronics)

## How CAN FD functions

The idea behind the CAN FD protocol is to increase the cycle-rate between network arbitration and the acknowledgment field of a CAN frame. Since at this stage only one node is able to send on the network the maximum data-rate only depends on the internal delay time of the CAN transceiver and the data signal (about 5 ns/m). In this way, it is possible to realize data-rates up to 15 Mbit/s with network lengths up to 40 m.

The CAN FD frame is backwards compatible and quite similar to the Classical CAN frame. A new feature is the bit BRS (bit-rate-switch) in the arbitration field, which is

## CAN FD-Frame (Standard Identifier 11 Bit)

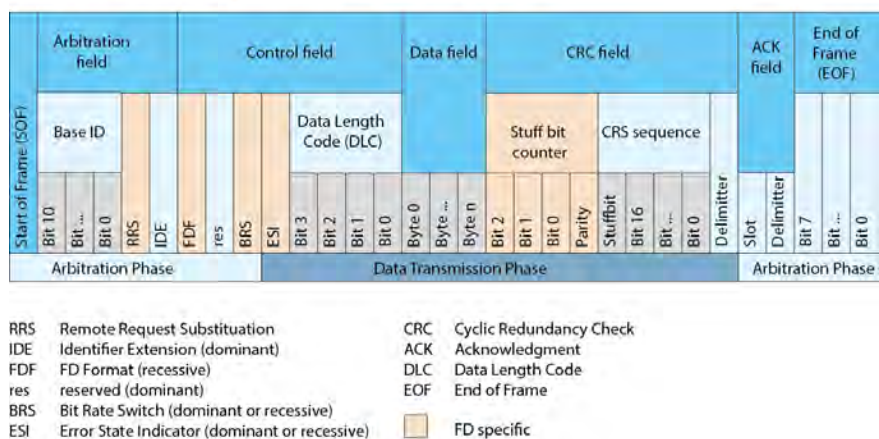


Figure 2: The structure of the backwards compatible CAN FD frame hardly differs from the Classical CAN frame (Source: ESD Electronics)



Figure 3: The Advanced CAN Controller (esdACC) offers an up to 32-bit wide interface, supports 64-bit time stamp and is able to generate a 100 % network load (Source: ESD Electronics)

used to recognize the higher data-rate. There is also the ESI (error state indicator) which is related to the control panel and displays the error-mode. In order to verify the data-field length the bit FDF (FD format) was defined as well as a three bit wide stuff bit counter. The sender counts the number of stuff bit and transmits the result as gray-coded 3-bit-value. The recipient also counts the incoming stuff bit and compares their values. The transmission reliability is increased by a parity bit attached to the sequence and by a fixed stuff bit in the CRC field. The RTR bit, however, is being ignored, since the CAN FD protocol does not support any remote frames. With correction

of the error detection mechanism of the CAN FD standard (ISO 11898-1/2015) such as adding the stuff bit counter the protocol reaches a Hamming distance of six. It is possible to distinguish up to five arbitrarily distributed bit errors leading to an automatic-repeated message. This makes the protocol an interesting option for safety-related areas.

### CAN FD controller for FPGA (esdACC)

In developing CAN components, it is possible to refer to regular CAN FD controllers or to CAN FD controllers in FPGAs. FPGAs are more flexible in terms of performance and functional density. In the past, common CAN controllers were connected to the host-system via 8-bit or 16-bit wide networks. The write access and especially the read access towards these controllers are quite slow compared to cycle times of modern CPUs (central processing unit). That is why ESD Electronics developed its own FPGA-based CAN controller called Advanced CAN Controller (esdACC). It offers an up to 32-bit wide interface, supports 64-bit time stamp and is able to generate a 100 % network load.

Another variant is the CAN FD controller for FPGA which supports the CAN FD protocol according to ISO 11898-1:2015. This controller is able to send and receive an ISO-compliant CAN FD protocol and to transmit the 11-bit-identifier base frame format and 29-bit-identifier extended frame format frames. The CAN FD transmission rate is between 10 kbit/s and 5 Mbit/s. Thanks to the FPGA technology it is no problem to implement custom-specific performance characteristics.

### PC board with CAN FD

The esdACC is the core component of the CAN interface CAN-PCIe/402-FD. The board provides a CAN FD transceiver and a connection to the PCI Express network as well as a 16 CAN frame deep TX FIFO. Hence, it is possible to generate a 100 % network load with a true back-to-back-transmission even when using non-real-time operating systems. Due to the 32-bit register interface CAN



Figure 4: The PC board CAN-PCIe/402-FD according to ISO 11898-1:2015 provides data speed up to 10 Mbit/s and transmits up to 64-bit user data (Source: ESD Electronics)

frames can be sent and received with a minimum number of register accesses. Further features include bit-precise CAN transmission and frame-precise cancellation of transmission with a minimum delay due to timeouts. Broken CAN FD frames in the FIFO are not blocked by low-priority TX signal. Also, host CPU loads are reduced by network

mastering towards RX and by the optional integration of a 32-bit micro-controller. The large FIFO for read and write operations as well as a precise time stamping enable further applications, e.g. for higher-layer CAN protocols. The esdACC IP core has been validated for Xilinx Spartan and Altera Cyclone FPGAs.

The CAN interface CAN-PCIe/402-FD can be applied universally and has been developed for the PCIe (peripheral component interconnect express) network. It provides one or two CAN FD interfaces according to ISO11898-2. For data transmission to the host memory the board uses network mastering. In this way, the latency periods can be reduced during I/O-transactions due to higher data-rates and a reduction of CPU loads. With the help of MSI (message signaled interrupts) the PC board can operate in hypervisor environments. Moreover, it supports high-resolution hardware time stamping. Handling of the CAN FD is significantly simplified by the monitoring and diagnosis tool "CAN real".

### CiA test passed

The user organization CiA (CAN in Automation) regularly [organizes so called plugfests](#) in order to test interoperability of CAN FD implementations. Furthermore, it is the goal to find out about the physical limits of transmission with respect to topology and data-rates. During these tests, data-rates up to 10 Mbit/s were approved error-free even at 100 % network load over a longer period of time. ESD Electronics took part at the plugfest with its PCI Express CAN interface CAN-PCIe/402 with CAN FD transceivers. Hauke Webermann, developing engineer at ESD Electronics, summarizes the results as follows: "The board interoperated perfectly with other CAN nodes. Communication with the CAN FD network even worked with bit-rates of more than 6 Mbit/s and the pure data reception was flawless up to a bit-rate of 10 Mbit/s."

### Exact time stamp in each CAN frame

The esdACC has a 64-bit time stamp counter which allows high-precision CAN frame transmission. It is the basis for the time-stamped TX-technology that runs parallel to the CAN FIFO and provides a high-priority TX-TS-FIFO with a depth of 16 CAN frames. Thus, CAN frames with time

stamps can be written into the additional ring buffer of the CAN driver, the TX-TS-queue. Afterwards, it passes the CAN frames to the TX-TS-FIFO of the esdACC within a set time window (TS-Window). Before the frame is forwarded to the CAN network, the time stamps are checked and expired frames are sent on a priority basis. In this way, the hardware time-stamping ensures real-time behavior despite of using non-real-time operating systems. In addition, a precise response is available covering the transmission time of each CAN frame. This may be used for higher-level protocols. Accordingly, all of the esdACC-based CAN interfaces provide a 64-bit-precise time stamp for the RX and TX direction. Also, a hardware timer supports software timeouts depending on the operating system. An optional Irig-B interface on the hardware allows the alternative use of the Irig-B time as an external clock for time stamping.

## Error injection

The CAN network is not only used in the automotive industry and in industrial automation but is becoming more and more popular in safety-related areas such as aerospace and medical technology. With the increasing safety requirements in these areas there is a growing need for verification, simulation, and testing. However, CAN controllers so far available on the market are not able to send erroneous CAN frames or to violate the standard CAN ISO 11898 in order to check behavior of erroneous messages. If, though, the esdACC IP core is supplemented by an error-injection unit, FPGA-based CAN interface boards, for instance the CAN-USB/400-FD, cannot only generate or simulate CAN errors but they are even able to intervene interactively in ongoing CAN communication. This requires only minimum extra expenditures compared to standard CAN hardware. The error injection units provide several injection modes, such as CAN arbitration, time triggered, or pattern matching, which allows combinations for complex scenarios. ESD offers a free graphical interface for the error injection unit, the esdACC Error-Injection-GUI-Tool.

## API/drivers and operating systems

The PC board CAN-PCIe/402-FD runs under WindowsXP/Vista/7/8/10 and Linux. The necessary CAN Layer 2 drivers are included in the scope of delivery. For real-time operating systems such as VxWorks, QNX, RTX, and RTX64 the CAN Layer 2 drivers can be ordered as an option.

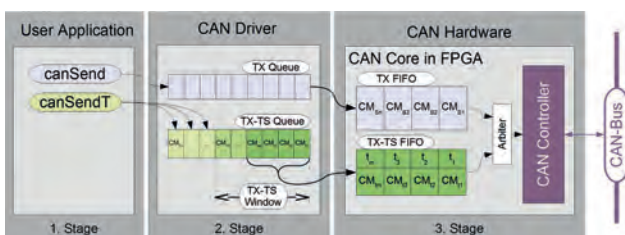


Figure 5: The esdACC has a 64-bit time stamp counter which allows CAN frame transmission; it is the basis for the time-stamped TX-technology that runs parallel to the CAN FIFO and provides a high-priority TX-TS-FIFO (Source: ESD Electronics)

The esdACC-based boards can be programmed via the programming interface esd-NTCAN-API. It serves to integrate controllers into Classical CAN and CAN FD based networks of real-time or non-real-time applications. The NTCAN implementation usually is a library supporting the application's API (application programming interface). It is combined with a CAN board specified device driver. Thus, the application programming is so to say independent from the operating system and from the device drivers, since the different CAN drivers in the operating system kernel were integrated as device drivers for various device classes. In this way, compatibility as well as interoperability between the application and the hardware are improved.

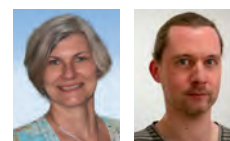
With respect to the CAN-PCIe/402-FD board a kernel-mode-driver is used which is in direct contact with the CAN controller (esdACC) of the internal network (PCI, PCIe etc.). It supports OS-specific performance features such as event driven and/or requesting CAN FD-I/Os, CAN FD frame interaction as well as firmware update for CAN FD modules with a local OS. Apart from these features, there is support for CAN FD node number mapping and non-blocking CAN FD-I/Os, listen-only-mode for non-interfering CAN FD monitoring as well as extended error information via the CAN FD status. The programming of the error injection and time stamped TX can be done with this board as well.

## Summary

The PC board CAN-PCIe/402-FD according to ISO 11898-1:2015 provides data speed up to 10 Mbit/s and transmits up to 64-bit user data. Thanks to a simple link-layer-protocol and to inexpensive controller and transceiver chips as well as low power consumption the CAN FD network is an attractive solution not only for the automotive industry. Machines and system components that have been using Classical CAN for some time can easily be migrated to CAN FD, because the existing cabling can be reused due the same CAN frame structure. With the help of the hardware time stamp technology, it is possible to nearly obtain real-time behavior even when using non-real-time operating systems. Applications in safety-related areas can be tested by means of error-injection units. Through several injection modes, such as CAN arbitration, time triggered, or pattern matching a combination of applications as well as complex scenarios can be evaluated.

The esdACC-based products can be programmed quite easily by using the ESD NTCAN-API. It serves to integrate controllers into Classical CAN and CAN FD based networks of real-time and non-real-time applications, and all this so to say independent of the operating system. ◀

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# *CiA technology days*

CiA organizes technology days to inform the CAN community on the current status of CAN-based networking, in respect to specific application fields or regions. Additionally, the events are a good opportunity to do some networking and to get in touch with other CAN experts. They are organized either as online or onsite event.

In general, CiA technology days are provided in English language. Some of them are also given in Chinese or Russian language.

# *CiA webinars*

The CiA webinars provide latest technical as well as market trends in CAN-based networking. CAN-related issues (e.g. CAN XL-, CAN FD-, CANopen-specifics) are presented within 45 min. Attendees are invited to discuss open issues in the Q&A session, subsequently to the presentation.

These webinars are intended for CAN users or decision makers from all over the world. Typically, CiA webinars are held in English language. Some CiA webinars, specifically intended for users in China or Russia, are provided in Chinese or Russian language, as well.

*For more details please contact CiA office  
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*[www.can-cia.org](http://www.can-cia.org)*