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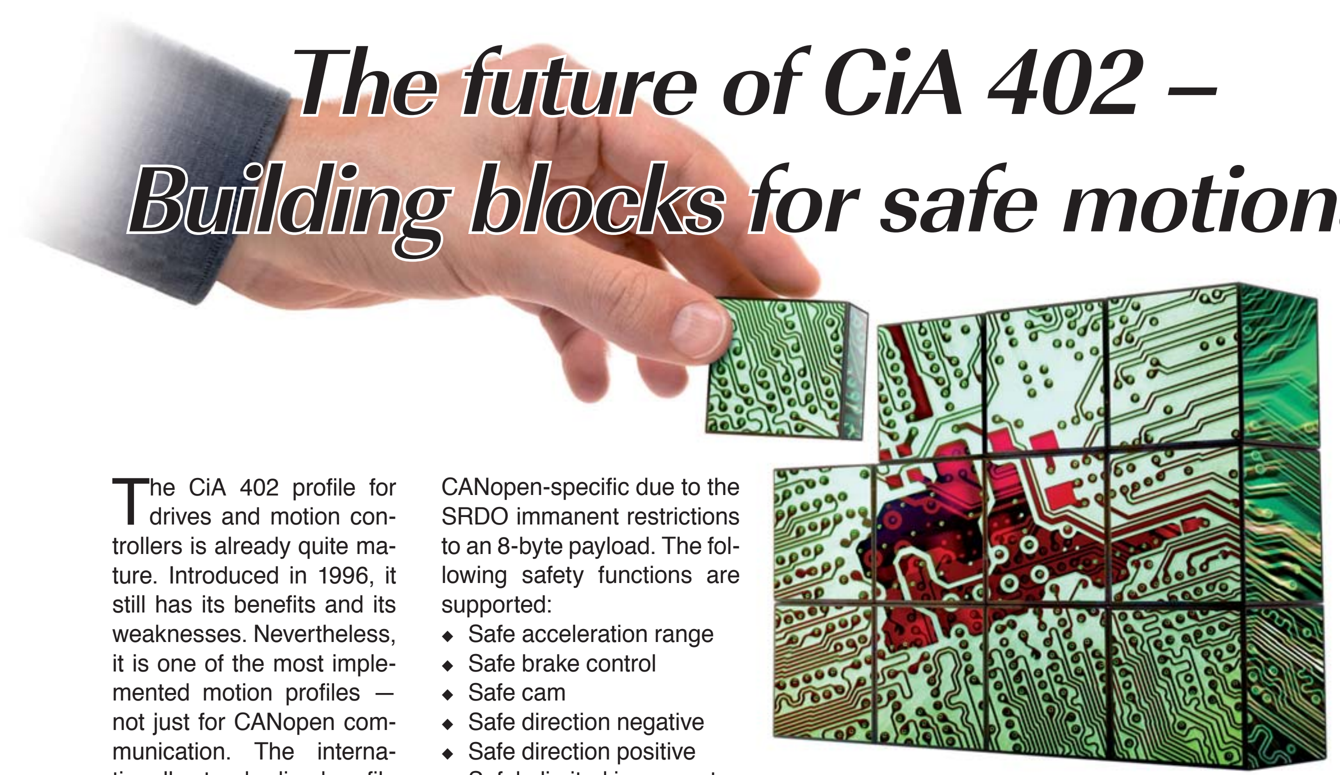
The future of CiA 402 – Building blocks for safe motions



The CiA 402 profile for drives and motion controllers is already quite mature. Introduced in 1996, it still has its benefits and its weaknesses. Nevertheless, it is one of the most implemented motion profiles — not just for CANopen communication. The internationally standardized profile (IEC 61800-7-201) has also been mapped to Ethercat and Powerlink (IEC 61800-7-301). In the next revision of this international standard, mappings to CC-Link IE and EPA will be launched as well. Of course, IEC 61800-7-301 also contains CANopen mapping. CiA will withdraw part 1 to part 3 of the CiA 402 specification, in order to avoid double-specifications and the risk of inconsistent descriptions. Nevertheless, the CANopen SIG motion control will continue to enhance the profile. New building blocks will be specified in additional parts of the CiA 402 specifications. The modular approach enables motion control manufacturers to implement optimized functionality in their products.

One of the most important extensions is the support of safety functions. The SIG will adopt the motion safety profile originally developed by the ETG (Ethercat Technology Group). The mapping to CANopen will be similar as to Ethercat in respect to the object dictionary (index and sub-indexes will be the same). However, the mapping to SRDOs is CANopen-specific due to the SRDO immanent restrictions to an 8-byte payload. The following safety functions are supported:

- Safe acceleration range
- Safe brake control
- Safe cam
- Safe direction negative
- Safe direction positive
- Safely-limited increment
- Safely-limited position
- Safely-limited speed
- Safely-limited torque
- Safe maximum acceleration
- Safe maximum speed
- Safe operating stop
- Safe stop 1
- Safe stop 2
- Safe speed monitor
- Safe speed range
- Safe torque-off

The safety functions comply with the corresponding IEC standards. The safety control-words and safety status-words are highly device-specific depending on the supported safety functions. Therefore, the profile provides a mapping function for command bits and status bits. Also, SRDO mapping is highly device-specific. The CiA 402-4 specification predefines merely the mapping of the safety control-word and the safety status-word into SRDOs. Additional safety target values and safety actual values may be mapped by the system-designer.

Additional building blocks for the CiA 402 CANopen motion profile are under development: Safe motion function (CiA 402-4) and PDO mapping for devices controlling asynchronous and synchronous motors (CiA 402-5)

Special PDO mapping

Besides safety, there is a trend to control asynchronous and synchronous motors with the very same device. This requires additional PDO mapping. Generic PDO mapping is not suitable, because the system designer needs to assign COB-IDs to the PDOs. Only the first four have pre-defined COB-IDs. Type specific PDO mappings for servos and stepper motors, respectively for frequency inverters overcome this problem, but do not support both kinds of motors simultaneously. The proposed additional PDO mapping will be specified in CiA 402-5, another building block of the CiA 402 series of specifications. It is intended that three TPDOs and three RPDOs will be pre-defined. The fourths will be used manufacturer-specific. The standardized PDOs contain the status word, respectively the control word. Additionally, they contain the values for vl velocity (first instance), position (second instance), and velocity (third instance). "With this mapping we use the very same EDS for power derive systems irrespective of if they control asynchronous or synchronous motors," said Günther Wenzel from Schneider Electric. *Holger Zeltwanger*

Abstract
The CiA 402 CANopen profile for drives and motion controllers will be enhanced in the direction of drives. Additionally, there is a new PDO mapping under development for devices that can handle asynchronous and synchronous motors using the same motion controller.

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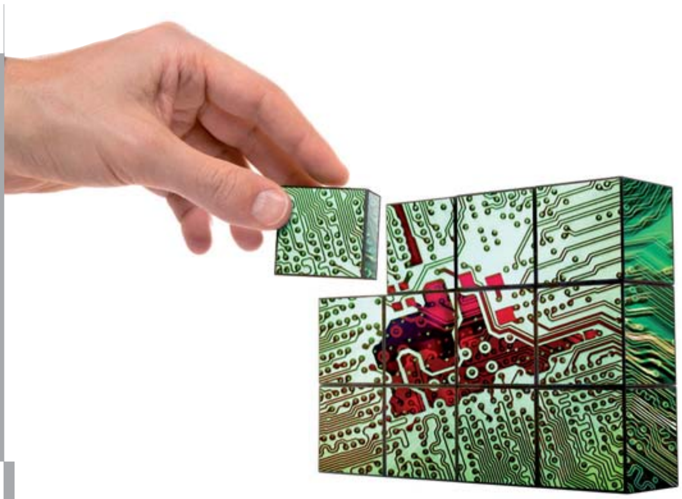

Cover story

The CiA 402 CANopen profile for drives and motion controllers will be enhanced with mappings to CC-Link IE and EPA in its next revision. There is also a new PDO mapping being developed, for devices that control synchronous and asynchronous motors.

Motion control

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Easy diagnostics with an app

Andreas Schneider, Burkhard Schranz

Introduction
High complexity, high costs, low storage capacity - automotive supplier Getrag Ford Transmissions GmbH has been confronted with these data logging issues in the past while trying to acquire measured data on the condition of its dual-clutch gearbox during operation. Optimeas developed an intelligent and cost-effective data logging solution based on their smart platform for the gearbox specialist, which can save data of 120 days.

An English taxi company with several hundred Ford vehicles got the ball rolling: "The taxi business always challenges the gearbox extremely: The engine is constantly turned on and off, there are high temperatures and the vehicle is mostly used for short distances," explained Andreas Schneider, responsible for the measuring technology at Getrag Ford Transmissions GmbH (GFT), Cologne. "Therefore we are highly interested in conducting customer measurements at dual-clutch gearboxes of the power shift type series to gather information on the gearbox condition during permanent operation." Sensors connected to the gearbox control unit help to collect data on shifting travels, hydraulic pressure, rotational speed or torque values - including potential error codes.

Figure 1: SmartCANLog

However, data loggers available in the company were only able to store information of 20 hours. Then the vehicle had to be brought to the garage to retrieve the data - or a technician had to drive to the customer. Both solutions didn't seem practical to Schneider. Therefore he started to search for a data logger with more storage volume, which was at the same time reasonably priced and easy to handle. "Data logger in the high-end sector are often very complex and require a high effort of programming and parameter setting, which always requires a technician. We wanted to avoid this, as far as possible - and hence provide our customers, i.e. the OEMs, with the possibility to just use the logger," explained Schneider.

The company found the suitable solution in Optimeas' smartCANLog. It is based on a highperformance ARM platform and is equipped with an isolated and ISO 11898-conform CAN connection. It currently supports log files such as RAW CAN and Multiplex CAN. The latter is used by the control unit of the gearbox. The device is equipped with a micro SD slot, which can be operated by the gearbox specialist in combination with 64 GiB memory cards.

Figure 2: Different housing options of the smartCANLog

Data of 120 days on one SD card

GFT records 140 channels in total using the multiplex procedure, which means that the data logger collects a maximum of 200 MiB per hour. They are compressed by a factor of 10, which results in 0,5 GiB per day. This allows the user to save the data of approximately 120 days on the smartCANLog. Schneider commented: "Compared to the previous solution, which only provided data storage for one day, this system offers an enormous advantage to us - in particular the easy

Figure 3: Employment of the device in the car

parameter setting." Connecting the micro SD card to a computer or laptop enables the user to install two software files: a DBC database file and a configuration file. The DBC file contains information about data sent by the gearbox. The configuration file defines, among other things, the size of the data blocks and whether or not data should be compressed.

Hence, the function of the logger is determined by the software. In order to keep the usage as easy as possible, Optimeas develops software specifically according to the requirements of the individual customer as well as the application. This basically means that an app is running on the smartCANLog, which can be flexibly adjusted. It is also possible to initiate pre-evaluations of measurement results on the logger - or the connection of an ODB2 diagnostics interface in case a direct connection to the control unit is not possible. Even testing benches can be flexibly expanded. Furthermore, software updates can be implemented within minutes. Customers can install their own software on the data logger with the help of an app loader.

Insert and start without programming and parameterization

After the installation the user only needs to insert the card into the logger. The logger recognizes exchanged or new SD cards automatically, closes running data collections, configures the measurement based on the DBC file information and starts collecting data automatically. The logger reads the existing DBC file and with it decodes received CAN messages completely and channel by channel. All data is marked with a time stamp and mutually stored in a data file on the SD card. The resulting data format can be compared to a video recording, which means that all data up to the latest data point is readable even in case of an abrupt stop of the measurement.

„The big advantage for us lies in the dramatically reduced effort," said Schneider. "Whereas before we had to continuously send technicians to the customer, with the logger that is only necessary during the first start-up in order to do the wiring and to show local employees what they need to consider when installing the logger in another vehicle. Afterwards data measuring runs automatically and support is not required." Today, GFT monitors the proper recording of the device via an acoustic monitoring system. Optimeas will upgrade the next device generation of the smartCANLog with a visual monitoring system.

Due to its high storage volume and low complexity, the logger is also a good solution for drive tests - no matter where in the world they are conducted. At the end of the drive test only the storage card is pulled out - and the measured data can be read. Climate conditions are irrelevant, because in case of fleet use the logger is installed in a splash-proof automotive housing. The device, which measures 13 cm x 7,5 cm x 3 cm, is usually installed in the vehicle's passenger compartment.

"The smartCANLog fulfills our requirements perfectly. And based on its functional range it is also very attractive in terms of price," said Schneider. "Traditional solutions usually provide extended functionalities, which we mostly don't require. And the more functions, the more complicate programming, parameter setting and fault tracing become." Therefore GFT decided in favor of the data logger of Optimeas. Not least because the functionality of the logger can be, despite its slim design, flexibly extended. Schneider mentioned measuring, for instance external data such as temperatures, voltage or currents. For that purpose Optimeas will extend its system by analog inputs. Alternatively it is also possible to wire CAN measurement modules with the CAN knot to be able to record this data with the logger: "With the CAN network you are able to set up, depending on the measuring task, an extensive measurement system based on the smartCANLog." ◀

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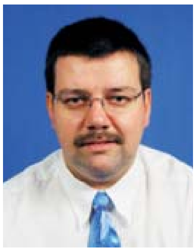

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Walking excavator uses J1939-linked hydraulics

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Abstract
The Swiss excavator manufacturer Menzi Muck has unveiled the first model of its next generation walking excavator series at the Bauma trade fair in Munich (Germany). The hydraulics in these construction machines are configured as a complete system of Linde Hydraulics components, including the electronic control unit ECU. A J1939 network links the control system devices.

Walking excavators — also known as spider excavators — are construction machines that move forwards on four wheels, which are connected to the undercarriage by legs. These legs can also be used to adjust the track width and the height of the vehicle over a wide range of dimensions, ensuring that the machines remain highly flexible and can be adapted to the surrounding conditions, both in drive mode and work mode, when the stabilizers on the legs are extended. This means that they are ideally suited for working in locations such as very steep slopes or in streams. An appearance on German TV show "Wetten, dass..?" in 2006 showed how flexible these machines can be. The impressive video is still available on YouTube and shows a walking excavator from Menzi Muck climbing over a 5-m concrete block - using the bucket as additional support - and proving just how appropriate the name "spider excavator" is.

Electro-hydraulic load-sensing system

At the Bauma 2013, Linde Hydraulics revealed - almost 30 years after introducing load sensing with the Linde Synchron Control system – the latest development of the LSC system for mobile machines. The LSC+ combines the characteristics of the tried-and-tested control system with the additional advantages of electronic control. The electronics identify the operator's intentions and set pump and valves to the highly dynamic or fine control range, depending on the requirement. The supplier offers the LSC+ as a complete system, including the electronic control connectable to J1939-based networks. A monoblock valve system, which was developed especially for the LSC system, takes on the hydraulic control functions.

The hydraulic monoblock valve system with electric piloting

Joint development at a high level

During the development of its walking excavator series the machine builder worked in close collaboration with Linde Hydraulics and Girtec, the Linde Hydraulics system partner based in Switzerland. Together, the companies developed a hydraulic system that utilizes the benefits of the Linde Synchron Control (LSC) and not only meets the ▷

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demanding requirements of the movements of a walking excavator, but also enables additional functions to be implemented. The J1939-based in-vehicle network connects all electronic devices.

Supply via tandem pump unit

At the core of the hydraulic system is a tandem pump unit. A load-sensing regulating pump of the HPR 105-02 E1L type for the open circuit supplies the working hydraulics with hydraulic fluid, while an HPV 75-02 E2 variable displacement pump for the closed circuit drives the traction motors.

The open circuit is controlled via a LSC monoblock, in which three directional control valves are integrated in a single cast housing. The pressure relief function is also integrated in the monoblock, and special functions can be implemented using an intermediate plate. The valves have a flow-optimized design and feature integrated pressure compensators and pressure copiers.

The special features of the LSC system include its "social load sensing" capability. This is a special kind of volume flow regulation for superimposed movements, which are frequently required for walking excavators. The relevant functions are supplied as required depending on how the driver moves the joystick, even if the requested flow volume exceeds the maximum possible pump flow rate. In this case, the available flow volume is divided amongst the actuators depending on their requirements.

ECU and joystick

The ECU for the walking excavator's hydraulics also comes from the Linde Hydraulics modular system. It maps the complete traction- and working hydraulics of the machine. The software developers at Linde have implemented some additional functions in the ECU, including the option to select pre-configured drive programs, such as an "eco mode" where the walking excavator operates in a particularly energy-efficient manner. The joystick, which the operator uses to operate the hydraulic functions, comes from Girtec. That means that virtually the entire hydraulic system, including the control electronics and man-machine interface, comes from a single source. ◀

Links
www.linde-hydraulics.com

www.menzimuck.com

Video of "Wetten dass...?" appearance

ECU with safety controller and J1939 interface

The Linc series of electronic control units for mobile machines provides safety functions up to performance level d (ISO 13849-1). The product by Linde Hydraulics is CAN-connectable and supports the J1939 application profile.

Core parts of the product are a function controller and a safety controller. Due to the redundant design, the unit can provide safety functions and thus is able to meet global legal standards for on-road machinery. The devices are used individually or combined, for hydraulic and electric drives, as well as combinations of both. Additionally to the drive components and the combustion engine, components such as sensors, joysticks and pedals can be integrated in the CAN-based control system.

Upon delivery, the control is preconfigured with the desired functions, machine characteristics and vehicle data.

Linc 2 safety controller featuring CAN connectivity

Single parameters can be configured via the LinDiag diagnosis software. The Linc 1 controller for electric drives and closed loop hydraulic propel drives features 10 digital inputs (4 pull-up, 6 pull-down), 6 analog inputs (0 V to 5 V), 4 current inputs, 3 frequency inputs, 4 digital outputs, and 7 PWM outputs. The Linc 2 unit provides 24 digital inputs (12 pull-up, 12 pull-down), 20 analog inputs, 9 frequency inputs, 8 low-side digital outputs, and 32 PWM outputs with current feedback.

V-model development of safety application

Christoph Filser, Tobias Heilig, Rolf Jung

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Figure 1: The OmniMove wheel with vaulted rollers on the periphery

Moving extremely heavy loads with radio remote control in areas with personnel traffic always has a risk associated with it. There are numerous ways to reduce the risk through safety systems and additional peripheral equipment. The companies Kuka and STW have jointly developed a new type of monitoring for a floor conveyer without a driver cabin. In this article a method is described, that illustrates how safety is achieved through a certified safety application in a freely programmable controller intended for safety relevant applications.

Kuka OmniMove is the designation for an agile type of drive for a floor conveyer. With its electric drives, the OmniMove provides unlimited maneuverability in all directions as well as rotation in place. Through its omni-directional drive wheels the vehicle may be freely navigated and steered in all directions by remote control, even in the narrowest spaces, with a positional accuracy of up to ±1 mm. Compared to conventionally steered wheels the logistics area required can be reduced by up to 50 % and the production area correspondingly increased.

The OmniMove wheel has a special rim with vaulted rollers mounted on the periphery. Positioned at a 45 ° angle, when the wheel is driven, two power components result, which are parallel and perpendicular to the drive axis.

Through diverse turning directions of the wheels, some of the power components compensate each other over the chassis while others combine to determine the motion of the vehicle.

Thus, in addition to straight, sideways, and diagonal travel, it is also possible to move in any curve or rotation around a freely defined middle point. The concept for the transitional movement is depicted in Figure 2.

The OmniMove vehicles are built for internal logistics and can lift loads up to 100 metric tons. There are ten different vehicle models with numerous customer specific options to meet any requirement. Anywhere from 4 to 20 drive wheels as well as numerous additional load wheels can be configured in order to facilitate the transport of large, unwieldy components.

Kuka needed to find a control system that would operate with many types of vehicles and fulfill customer specific requirements. For many years Sensor-Technik Wiedemann (STW) has offered fast and flexible control solutions in mobile applications with its ESX family of controllers. STW has continued this series with the ESX-3XL 32-bit controller. The controller was conceived to provide a high level of flexibility. With up to six internal expansion boards, 84 of the 162 possible connector pins can be configured with distinct functions, from simple I/O to encoders, special I/O, data ▷

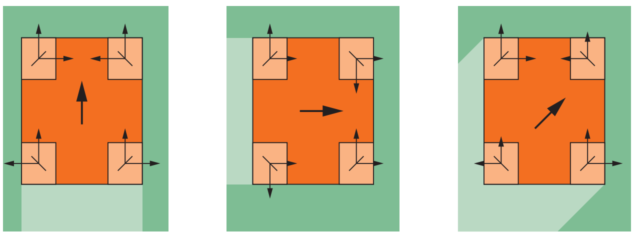

Figure 2: Concept of the transitional movement

storage and communication interfaces. The mainboard of the ESX-3XL also offers software configurable I/O functions. The 28 available inputs are all 12-bit multi-functional inputs (MFI), i.e. the application programmer can define their function. Initialization functions allow the programmer to specify each input as an analogue current or voltage input (measurement range: 5 V, 10 V or 40 V) or as digital/RPM (frequency) input. Furthermore, the 3XL software library allows an application specific function to be called when the input signal changes (callback function). The RPM signal covers frequencies from 0,6 Hz to 20 kHz. Filtering may be applied to the MFI signal through software, with configurable debounce times and low pass filters.

All outputs can produce PWM signals, are protected against short circuit and are controllable via 12-bit current measurement and status feedback for complete diagnosis.

The core of the controller is a 150 MHz Tricore processor with 4-MiB RAM, a 6-MiB flash memory and a 32-KiB EEPROM parameter memory. The mainboard has four CAN interfaces and a serial (EIA-232) port. Additional communication interfaces (including Ethernet and USB) may be added by means of the expansion boards.

Functional safety

Recent experience with numerous applications has shown that the customer requirements for functional safety are growing. With increased integration of controller and memory components, safety requirements may be fulfilled in an economically viable manner, alongside the normal functionality. Where does the need for functional safety oriented electronic controls originate? These controllers reduce the risk of

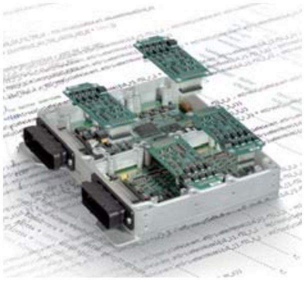

Figure 3: Controller ESX-3XL with expansion boards

serious accidents in applications that include functions relevant to the safety of people and things in the environment. This assumes that the criteria for functional safety are correctly fulfilled. “Safe” is defined here as a situation where the risk is smaller than the generally accepted risk limit. An acceptable risk level is defined for the application. This risk is determined by a combination of the probability of occurrence and the severity of the damage.

Functional safety is a part of the overall safety of a system that depends on electronic systems, other safety technologies, and external risk factors. The requirements on the functional safety must be defined before certification can take place. Which safety standards should be applied? The standards are mostly defined by the application. The application described here is a floor conveyer, which can transport loads of up to 100 metric tons. Therefore this vehicle must meet special safety requirements for industrial trucks with respect to braking distance and subsequently the maximum allowable vehicle speed.

The risk analysis of this application resulted in performance level PL-c from the guidelines for machine safety DIN EN ISO 13849-1 as being applicable for the OmniMove. STW developed the safety requirements and a safety plan for the OmniMove and the Institute for Work Safety IFA in Sankt Augustin approved the requirements.

In the current project these conditions are implemented with a safety oriented software module on the ESX-3XL electronic controller. For that software module the requirements for safety relevant application software according to DIN EN ISO 13849-1 apply. The safety architecture is conceptualized based on Category 2 of the standard. The control unit consists of a freely programmable main controller and an independent system supervisor (SSV). The SSV is also a programmable controller that monitors the main controller by assuming watchdog functionality, monitoring system voltages, testing logical events and thereby allowing the utilization of the controller in safety critical applications. The main controller has diagnostic routines that continuously check the entire system in hardware and software and place the system into a safe condition in the event of a failure. The safe condition in this application is emergency stop.

As a result of their design the OmniMove vehicles can reach speeds up to 6 km/h. The risk analysis however produced significantly lower allowed maximum speeds. Two conditions for maximum speed limits are described. ▷

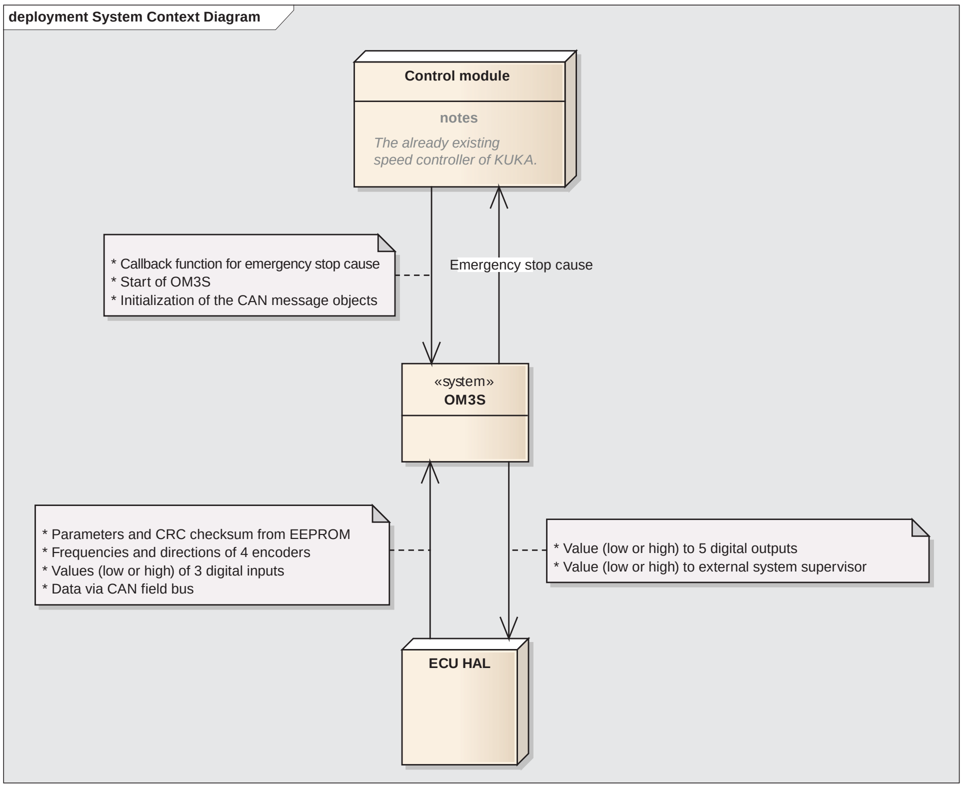

Figure 4: Overview of the OM3S system

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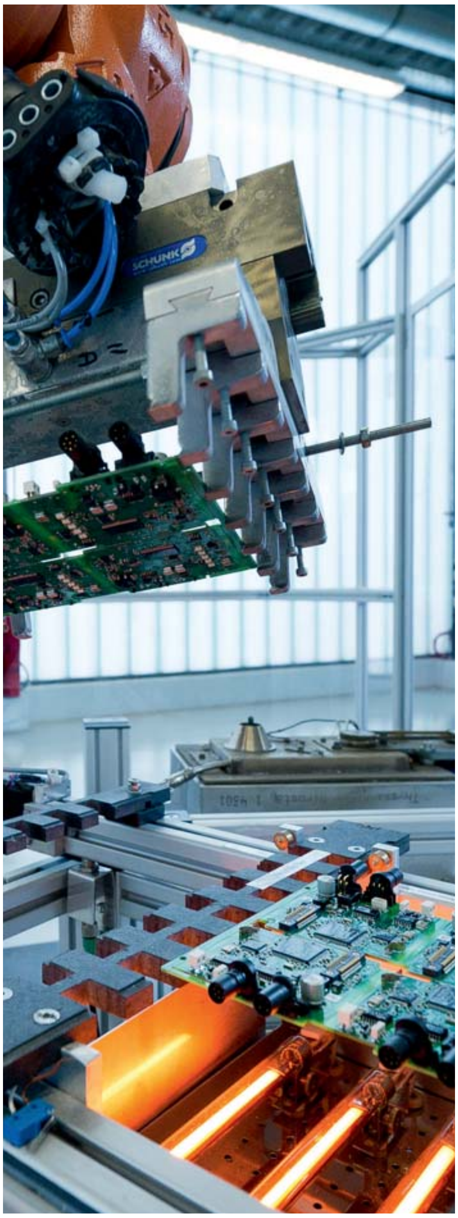

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Figure 6: OmniMove, an extremely agile type of drive for a floor conveyer

The first condition is for the load condition. For an empty vehicle the maximum allowed speed is 3 km/h, which is the normal walking speed of a pedestrian (for example, the operator with the remote control unit). For a loaded vehicle the maximum allowed speed drops to 1 km/h.

The second condition pertains to vehicles that are outfitted with laser scanners that create a protection zone around the vehicle. Laser scanners can bring a vehicle to a stop as soon as they sense an obstacle (e.g. personnel) in the path. There are situations where the laser scanner must be switched off (override conditions), for example driving through narrow warehouse spaces. To guarantee safety under these conditions the maximum allowed speed is reduced to 0,1 km/h.

The maximum allowed speeds are specified based on defined stopping distances during an emergency stop. The OmniMove vehicles are intended for many different tasks, meaning a large number of design variants and operational situations. The risk evaluation can therefore also differ significantly, and the maximum speed must be adjusted accordingly. The maximum speed is set individually for each vehicle type through software parameterization.

The safety concept

The safety oriented software module for speed monitoring has the tasks "Identification of the currently allowed maximum speed" and "Calculation of the actual speed of the vehicle from available signals from three wheels (the fourth wheel provides a redundancy in the speed measurement)".

If the actual speed is too high or any other error is sensed, an emergency stop must be initiated immediately.

The name of the developed system is OmniMove Speed Surveillance System (OM3S). It has the following core tasks (functional requirements):

- Reliable recognition of the load condition of the vehicle by redundant load sensors,
- Reliable recognition of the status of the laser scanner protective field (active or disabled by the override button) by redundant signal paths,
- Determination of the currently allowed maximum speed based on load condition and override information,
- Reliable reading of the encoder signal from the individual drive wheels of the vehicle through redundant sensors with analogue and/or digital outputs,
- Calculation of the actual speed of the vehicle from the drive wheel encoders (this can be accomplished by a mathematical model with the x/y coordinates and the instantaneous rotational velocity of the three drive wheels),
- Fault recognition through plausibility check.

Every recognized fault or a speed in excess of the presently allowed maximum speed must result in an emergency stop for the vehicle (the safe state). The monitoring software must be suitable for all conceivable configurations (geometry, size, number of driven and auxiliary wheels, etc.) of the vehicle. In order for the system to meet the requirements of a safety software with performance level PL-c according to DIN EN ISO 13849-1 the following quality attributes must be fulfilled:

- The parameters loaded in non-volatile memory (EEPROM) must be verified with CRC checksums,
- The integrity of the main memory (RAM) must be ensured through suitable means,
- Program flow control must be monitored with a system supervisor with watchdog functionality to guarantee the correct program processing.

Among the overall requirements for OM3S is the prerequisite that it must be implemented on the PL-d certified safety ESX-3XL controller with integrated hardware diagnostics. The controller's hardware diagnostics is divided into two parts:

- Start-up diagnostics that are executed when the controller is switched on and test all of the basic functions, for example the safety relay; these tests cannot be repeated at a later time because they would affect the operation of the vehicle,
- Periodic tests of memory and CPU for the integrity of content and function, which run in the background, parallel to the application software.

In this project Kuka already uses the controller to run the vehicle's application software. The OM3S will also run on this controller with interfaces to:

- The vehicle control software from Kuka, and,
- The Hardware Abstraction Layer (HAL) of the controller.

STW's development process

The specifications of this project are processed exclusively in database oriented ▷

General information on architecture reviews

Frequent and early reviews prevent the development effort of going in the wrong direction or into a dead end. Through the process of explaining ones' own design to another person, shortcomings in design will become evident. It will be clear whether the underlying considerations are logical and complete.

Reviews also uncover misunderstandings, differences in interpretation or incompleteness of the requirements. Reviews during the design process should be done to explain the solution, why it was done this way, what alternatives there were, and why they were not chosen. In this way the work of the architect can be reproduced and either confirmed or corrected. The review is an important test that can prevent errors from being propagated.

requirements management software. This promotes the atomic capture of individual requirements (individual entities) that are referenced by number and can be individually tested. This leads to testable requirements and traceability of the individual requirements through the life cycle of the application and back to their origin or source. The individual requirements go through formal reviews by various working groups based on the following criteria, and the results are documented so that they can be incorporated into subsequent versions of the specification: unambiguity, completeness and testability.

The system architecture must be designed before the design of the individual software components. A second software architect from outside the project must review the architecture and then it can be refined.

There must be a unit test written for each function that is implemented in a software component. Thus, each software change can be tested completely and preferably automatically.

This ensures that all previous functions still work error-free after the change. After the requirements are put in the specification, they are evaluated for testability.

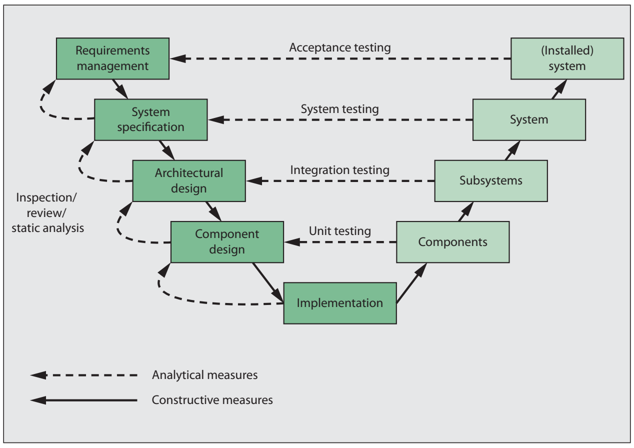

Figure 5: The development process of safety software follows the V-model

System tests will then be defined for testable requirements in a system test specification. A configuration manager is assigned to administer the system configuration and to maintain an overview of which versions of the individual development components (specifications, architectural designs, system test specifications, implementation, test protocol) go together. The importance of the software tests is emphasized with identification of a test manager. The test manager will be assigned this role by the project management. He produces a test management plan, organizes the tests and coordinates the activities of the software testers.

The software testers also have the task of managing defects. The defects must be entered into a ticket system. Once entered, the processing of the defects will be systematically tracked, with their status (e.g. Developer Analyzing, Tester Confirmed Resolution, etc.) Once a first version of the specification is completed and released, work can begin on the software architecture and system test specification. In practice, work can begin earlier when a stable set of requirements have been identified. After this, desired changes can only be introduced through a change management system. Each change request is entered into the ticket system and must go through a series of different status conditions before it is finally approved and implemented.

With the conditions for functional safety fulfilled, the OmniMove should operate without unnecessary interruption. The availability of the machine is a very important benchmark for the customers. Initial tests showed that the availability was too restricted. In order to improve the availability, the safety application was modified to compensate for unexpected effects from vibration in the vehicle and the effect on the wheel speed measurement. Filtering of the wheel sensors was required to ensure a stable evaluation of the actual vehicle speed. Multiple drive tests, extensive technical discussions with safety experts and eventually modifications to the OM3S specification were necessary to find a technically and commercially viable solution and deliver a successful, safe product.

Conclusion

The software application fulfilled all aspects of functional safety, while maintaining both the availability of the system and the flexibility in terms of the large number of vehicle variants. Parameterization of the software is a necessary part of the safety considerations, and ensures the flexibility to accommodate future customer requirements, and the inherent changes to the risk situation. ◀

The System Context Diagram (SCD)

A System Context Diagram (SCD) depicts all external entities and can then interact with the system.

- The SCD depicts the system to be built as a black box.
- It graphically depicts its interactions with external entities.
- It determines the flow of information and control between the system and the external entities.

A context diagram should depict in a simple manner what kind of relationship the system has with the surrounding participants. It should not attempt to represent the architecture of the system. In this overall view the system is handled as a black box. The emphasis lies on how the system relates to its environment, not on its architecture or decomposition.

"We open our systems to facilitate simple integration of third-party products"

Company
Jetter AG with nowadays about 250 employees was founded in 1980 by Martin Jetter, who had it listed at the stock exchange in 1999. The company has subsidiaries in China, Great Britain, Switzerland, and the USA. In 1999, the JetWeb Industrial Ethernet approach was presented at Hanover Fair. In the course of time, the company acquired Ebelt (2000), Futronic (2005) and Control Developments (2008).
In 2006, the JX3-I/O system was introduced, which includes the JX3-BN-CAN bridge module.

Link
www.jetter.de

Related articles
Electric servo drives prove themselves in outdoor use – page 38

Since April 2013, Christian Benz has been leading the technology and sales staff in the Jetter AG. At the beginning of next year, he will assume the chairman position of the Management Board. "CAN was, is, and will be one of our network technologies which we believe in," said Christian Benz. "The Jetter AG was the first company which introduced Ethernet into industrial automation. "However, for applications that do not require high bandwidth we have been using CAN and CANopen for many years," explained Benz. The company is committed to support open standards such as CANopen and Ethercat. "We will make some announcement during the SPS IPC Drives exhibition in Nuremberg," he added. Nevertheless, the company does not intend to become a device supplier, it will remain mainly a turnkey system provider. However, the integration of third-party products with CANopen and Ethercat interfaces as well as additional communication technologies into Jetter control systems will be simplified.

Figure 1: "For mobile machines we have developed a modular control unit, which can be used in different kinds of vehicles," said Christian Benz, the director of technology and sales

The company headquartered in Ludwigsburg (Germany) has two business areas: industrial automation and mobile automation. In industrial control systems, CANopen is used as the preferred network only for digital and analog I/O modules. Drives and motion controllers use the company's Ethernet-based network solution.

In the mobile automation business, the company provides CANopen and Isobus (ISO 11783) products as well as CAN-related solutions with proprietary higher-layer protocols. "Industrial automation is our main business," explained Benz. "Some 80 % of the income is generated from industrial control systems." The most important industrial customer is Emhart Glass (Switzerland) belonging to Bucher Industries (Switzerland).

Emhart Glass is a leading supplier of equipment, controls and parts to glass container industry. With expertise in glass container forming, glass conditioning, gob forming, ware handling, cold end inspection, refractory parts and quality assurance, the company's machines and systems are ▷

Figure 2: The JVM-104 human machine interface designed for outdoor applications is IP65-rated

sold worldwide. The control systems designed by Jetter use CANopen networks for "slow" I/Os clocked in milliseconds. The company invests about 20 % of the turnover in research and development. "We have a high vertical integration," said Christian Benz, "which is why we are flexible and can provide a high quality."

In mobile automation, the company has several key customers. Rosenbauer (Austria) makes fire-fighting trucks, Grimme (Germany) produces potato harvesters, and Bucher Municipals (Switzerland) manufactures municipal vehicles. The two electric drives used by Grimme in a prototype vehicle improve its harvesting performance. Operation even in wet fields under harsh environmental conditions is possible.

Additionally, Jetter has developed a version of the Jetviewsoft development tool specifically for the Isobus market, called ISO-Designer. The ISO-Designer is a high level tool to design screen masks for HMIs on agricultural machines. These masks are distributed via the Isobus protocol on the CAN network from the ECU to the (ISO) terminal. Jetsym, the programming tool with the Jetsym STX plain text high-level language, is continuously adapted to meet market and customer requirements. Accordingly, the latest version can run under Windows 8 and contains functions that make programming, diagnostics and commissioning more efficient. For example, recordings in the integrated oscilloscope can also be made via CAN networks. Previously, this was only possible via Ethernet or serial interface.

At the Bauma exhibition in Munich (Germany), the JVM-104 human machine interface (HMI) has been introduced. Its 3,5-inch TFT display with LED backlight is installed in a rugged plastic enclosure. This product is designed for both day and night use due to the backlit keys and the light sensor, which automatically adapts the illumination of the display to the brightness of the surroundings. The HMI is equipped with four function keys and is available with an optional Digipot. The operating temperature ranges from -20 °C to +65 °C. Thus, it can be used for outdoor applications. The HMI runs Windows CE as its operating system. Peripheral devices can be controlled via CAN interface. Two multi-purpose inputs and four PWM outputs are available as options. The device can be equipped with an optional USB and Ethernet port. Typical applications include automated construction and agricultural machinery, but also traditional industrial automation. ▷

Bucher Industries took over 90 percent of the Jetter shares

Bucher Industries (Switzerland) offered via one of its subsidiaries a price of EUR 7 (about 150 percent of the market price) to shareholders. The Swiss group has held a stake in Jetter since 2005, which most recently amounts to about 30 %. Bucher Industries is planning to strengthen the competence of the Jetter company in the area of automation solutions and to expand its market share. The aim of the takeover offer is to acquire all of the shares in Jetter AG. The Supervisory Board and the Management Board of Jetter supported the takeover offer.

Since 2002, Jetter has been an important partner of Bucher Industries, not only developing and manufacturing electronic control systems for Emhart Glass, but also supplying the electronics for municipal vehicles manufactured by Bucher Municipal. In the past two financial years, Jetter generated on average around 50 % of its turnover with the Bucher Group, with the majority of that turnover being accounted for by the Emhart Glass division.

The old and the new chairman of the Management Board (Martin Jetter on the right, Christian Benz in the middle), and CFO (chief financial officer) Günter Eckert (on the left), who is responsible for finance and production

The founder of the company, Martin Jetter, will continue to be responsible for the development. Nevertheless, he intends to resign from his position as member and chairman of the Management Board of Jetter AG at the end of the year, and to subsequently take a seat on the Supervisory Board. Christian Benz will succeed him as chairman. He said, "Our goal must be not only for the company to be seen as the supplier of technology to the Bucher Group, but also for it to continue securing market share in the industrial and mobile automation segment through highly active market cultivation."

Figure 3: "We see great potential in China, both in industrial and in mobile automation, and are convinced that our innovative products will quickly find their buyers here," stated Bruno Dörig, manager of the subsidiary in China

At Bauma, the company also launched the JXM-TX5 controller for hydrostatic drives, which was designed for outdoor use. Among other things, it meets all requirements for use in harsh environments, such as vibration and shock resistance. It comes in an IP68-rated enclosure. The operating temperature ranges from -40 °C to +85 °C. The product communicates via two CAN interfaces using CANopen and SAE J1939 protocols. A permanent Eco mode reduces exhaust emissions and fuel consumption. The controller is configurable and can be parameterized. This makes it possible to start on an incline, or drive in mountainous conditions with full-load or idle, without the driving wheels locking up. An ABS control unit can also be connected to the controller. The software of the control unit enables jerk-free acceleration and deceleration. Trips at a constant diesel engine speed, as well as the speed-dependent adjustment of the hydro-pump and engine are also possible. The built-in load limit control function prevents the diesel engine from stalling. A typical application is the hydrostatic drivetrain, which can be found in most municipal vehicles, or agricultural and construction machinery.

Jetter has had a presence in China with its own branch office since the middle of 2012. Bruno Dörig has been managing the office for the first few years. As an application engineer, he had already been supporting various customers in the Far East for a number of years. Dörig is therefore familiar with the culture and characteristics of countries in that part of the world. Before leaving for China, he headed up the Product Management department in Germany. The Chinese branch office provides customer advice, sales and order processing, as well as technical support locally. "Closeness to the customer is very important in this fast-growing market. This is why we also want to offer all these services locally," said Dörig. ◀

Encoders make mobile elevating work platforms flexible

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Introduction
Construction and maintenance work on buildings and houses used to be done with expensive scaffolds. In the 70s of the last century mobile elevating work platforms came on to the market reducing the effort and costs for the work at places difficult to access. The first platforms had a height of 10 m to 20 m. This range is now increased to 100 m. But not only the height was important. The total operation distance was also of interest. (See Figure 1)

Figure 1: The LEO platform with stabilizer

To reach areas in buildings that are difficult to access, the elevating work platforms needed to become more flexible. Now encoders are required to give set-points and values for rotation and inclination. The control takes care of the stability and the balance to prevent falling of the platform. The speed of moving and the load of the platform are also considered.

The company Teupen developed a specific control for a large variety of their elevating platforms. This control is based on fuzzy control logic to react fast enough to dynamic movements and loads. Important test points are within the tracked chassis moving the complete platform. Further measurements are done in all joints and at the basket.

The inclinometers of the series NBX65 are based on MEMS technology (micro electro mechanical system). They detect the inclination within a range of 10° to 180° with an accuracy of 0,5°. The resolution is 0,01°. They measure one or two axis and generate a CANopen, analogue or SSI output signal.

The first approach to make elevating work platforms smarter was using standard electro-optical encoders with SSI interface. They were of singleturn type measuring 360 ° with 12 bit resolution. They allowed for continuous rotation and started from zero again after a complete round. As the slewing ring of the tracked chassis and the pinion of the measuring device form a gear the measuring device needed to be of multiturn type. The multiturn types have an internal gear box that can measure up to 4096 rotations.

The multiturn types were mounted to the tracked chassis of the platform measuring the angle of rotation. A similar application can be found in all mobile cranes, bucket excavators and motorized concrete pumps.

Standard optical encoders were doing well for the technical requirements but safety regulations required additional effort. ▷

Figure 2: Elevating platform LEO for exceptional height and distances

Figure 3: T-series encoder in two-chamber technique

Figure 4: TRN64 encoder for slewing ring and gearwheel free from backlash (ZRS)

The measurements needed to be carried out redundantly to make sure that in case of failure of any component incl. sensors nobody gets injured. This is in accordance to SIL2 (safety integrated level 2). To avoid two encoders on a ll measuring points TWK developed encoders with duplicates of all components that are susceptible to failures. The electro-magnetic encoders of the T-series give the possibility to duplicate all relevant components inside the device. So the mean time to failure (MTBF) was increased.

The development of a special encoder for slewing ring applications was the consequent result of that requirement. The electro-magnetic encoder TRN64 is equipped with redundant sensing and transmission components. It is to be mounted to a gearwheel free from backlash (ZRS). This gear wheel is also a development from TWK. The gearwheel is made of high-grade synthetic. It is solid and has a well-defined flexibility at the contact points. Standard gearwheels for backlash free operation consist of several components including a spring. Standard gearwheels are not applicable in safety relevant application as their components have a limited lifetime. Another feature of that special encoder is that it will never have an "overflow". As the circumferences of slew ring and gearwheel are known the micro controller inside the encoder calculates the position correctly even when the internal number of 4096 rotations is exceeded. The TRN64 has a CANopen safety interface and is SIL2 certified.

The singleturn type TBE with SSI interface is also electro-magnetic. The sensing elements are based on hall effect. The encoders are built in two-chamber technique so the electronic chamber can be potted. The extended temperature range of -40 °C to +85 °C, which in former times used to be an expensive option on the electro-optical devices, is now the standard range. The redundant SSI output and the redundant supply voltage are connected with two separate plugs. Even if one connection fails, the application can continue working correctly. The control can detect the failure and take measures to drive the application into a safe position according to the safety regulations.

The housings of the encoders are made of aluminum or of stainless steel. The thickness of the wall is 5 mm to 10 mm. The shaft is made of 12 mm stainless steel and can take a load of 250 N axial and radial. A sealing ring around the shaft prevents water from entering the encoder at the mechanic chamber.

Figure 5: TRN64 encoder for slewing ring and gearwheel free from backlash (ZRS)

As the electronic chamber does not contain moving parts it can be potted. The protection class is IP69K. The encoders can be used in harsh environment.

TWK offers a range of encoders and inclinometers with CANopen safety and PROFIsafe interface in redundant technique certified by German TÜV. ◀

Systeme Helmholz: 25-year anniversary

Links
www.helmholz.com

Milestones of the company
1988: Foundation of the Helmholz engineering office
1990: First S5 products
1998: S7-300 I/O product family
1999: First distributor overseas
2001: Profibus connector
2003: Netlink gateway
2006: Office in China
2007: Helmholz daughter in Spain
2008: Own building in Großenseebach
2009: REX 300 Ethernet router
2009: Helmholz daughter in France
2011: Helmholz daughter in Benelux
2012: TB20 modular I/O system

Figure 1: Manfred Helmholz (right) is still the CEO, but daily business is done by Carsten Bokholt (left) and Karsten Eichmüller (middle)

Twenty-five years ago, Manfred Helmholz established an engineering company for software and plant commissioning with two employees in Erlangen (Germany). Just two years later, he launched the first Siemens S5 product. Today, the 85-employees company serves its worldwide customers through a network of sales offices and distributors from its headquarters in Großenseebach, just a few kilometers away from the company's first home. But today the building is not rented, it is owned by the company. "And we need more space," said Carsten Bokholt, looking out of the window. "We plan to double the size of the current building; the land is already bought."

CAN-related business accounts for 10 percent of the company's income. "Nevertheless, CAN products are important," stated Bokholt, who is responsible for research and development. "In particular, the Profibus DP to CANopen coupler and the CAN 300 PRO interface module are our sales drivers in the CAN business." In addition, the company offers CAN connectors, and a CAN bridge device. The company sells more than 10000 CAN products annually. Carsten Bokholt did not want to answer questions about a CAN 1500 interface module: "This can currently be neither confirmed nor denied."

The CAN devices are used in many different ▷

Figure 2: The young Manfred Helmholz in 1988 at his desk

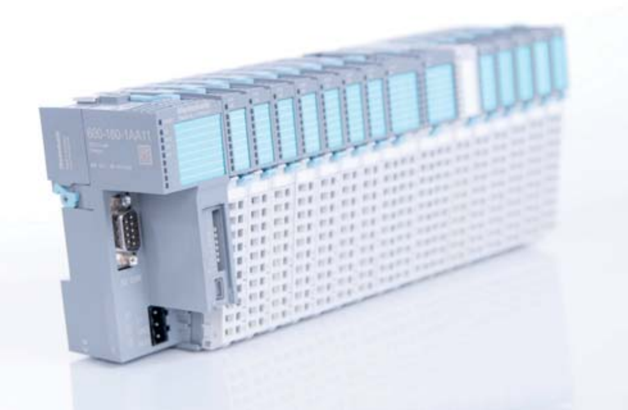

Figure 3: The TB20 modular I/O system comes optionally with a CANopen bus-coupler

machines, including extruder downstream devices compliant with CiA 420 profiles. They are also used in ship automation systems and in automotive test stands. Recently, the company introduced a ProfinetIO-to-CANopen gateway. "It doesn't implement the CiA 309-4 specification," said Bokholt. "It is transparent to the ProfinetIO master, which makes configuration much easier." All hardware and software developments are done in Germany. Even end-assembly and testing of the boards happens at the company's headquarters.

The company has developed the TB20 modular I/O system, which was already pre-announced in 2010. The available CANopen bus-coupler complies with CiA 301 and partly with CiA 401 (PDOs and process data). The extension module series comprises digital and analog I/O functionality as well as dedicated functions (e.g. counters). The configuration of them is proprietary and doesn't use the standardized CiA 401 parameters. The ergonomic design has overcome disadvantages of some "early birds" from competitors.

Energy measurement is a hot topic. The company will provide related TB20 I/O modules in the near future, which will measure for example the consumed power. CiA has currently released the corresponding CiA 458 CANopen profile for measuring energy consumption.

The TB20 business has not taken-off yet. "The design-in phase of most applications is longer than a year," explained Bokholt. "But we have already won a lot of contracts. It is just a matter of time until the TB20 sales will increase. It is one of our key-products for the future."

Manfred Helmholz's commitment to "Made in Germany" will be continued in the future. "Our customers expect high product quality," stated Bokholt, "and we want to satisfy them with products developed and manufactured in Germany, the home of quality." The products are tested in-house and by external independent laboratories (e.g. EMC tests). ◀

CANopen device configuration editors

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Introduction
This article presents the main principles of device configuration editors as two case examples. The editor in the first example is targeted at CANopen encoders. It was possible to implement a generic editor because the encoders share a uniform logical structure [14]. The second example presents an editor for general purpose I/O devices. Because of the generality, device or device family specific editors are required [13]. Both device profiles are supported by a large number of devices, which helped to find out the main commonalities and differences.

In modern, distributed control systems re-use of functions expects the use of a limited number of components in as many instances as possible. Each component instance requires unique settings assigned during the system design. A common misunderstanding is that CANopen is only a serial communication protocol and therefore parameterization is considered a part of software development. Such an approach easily leads into system configuration inconsistencies, because system level configuration management is missing. Standard DCF files are used for storing the settings of CANopen devices. The simplest approach is to manually configure each device for a prototype system and store the settings of each device into corresponding DCF file. After storing the settings, they can be used for manufacturing of the systems with equal settings. Further challenges can appear during the assignment of device parameters. Raw configuration files with raw parameter values are typically accessed by software developers, who do not necessarily have a detailed understanding of sensor, drive and system behavior. Control and system designers are not necessarily able to fluently edit the raw files or assign the correct raw values. Typical results have been incorrect or even missing parameter values, because the necessary parameters with their descriptions are described only in text documents. In addition, product specific commissioning tools with dedicated bus access are available for some products [2], which will lead to a need for too many different bus interfaces. Functional safety requirements are tightening up and setting requirements for well defined and documented processes [8] [9]. Main targets are to get managed structural descriptions for the systems, to help with the selection of correct components, and to use them according the specifications and with correctly set parameter values. Following standardized processes results in understandable designs, including design documentation.

```
[Tools]
Items=2
[Tool1]
Name=Device Settings
Command=encwiz.exe $DCF
Wait=1
Make=0
 : :
```

Figure 1: Example [Tools] section in an encoder EDS file

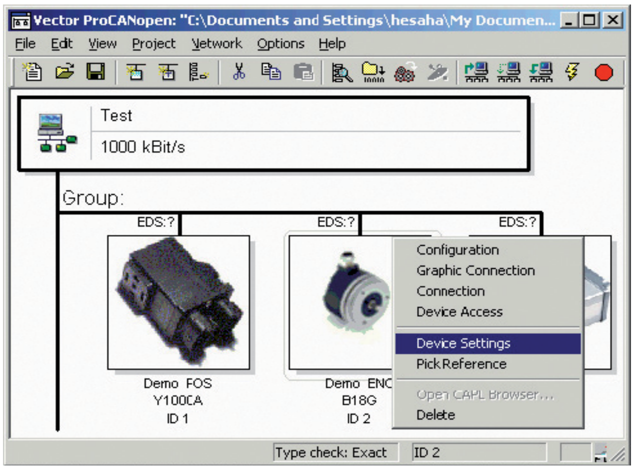

Figure 2: Launching the device editor of the system design tool

CANopen possibilities

Instead of only communication protocols, CANopen specifications include a thorough layered description of communication services, system design process [3] [10], configuration files [10] [11] [12] and integration mechanism between various design tools [11]. CANopen device profiles provide an efficient approach to the re-use of common measurement and drive functions in systems. It has been proved earlier, that using CANopen to coordinate the development of distributed systems significantly improves both quality and efficiency of the software development [3] [5].

CANopen also helps to manage a system's complexity and tolerate differences between components and a sytem's life-cycle. [4]. Following the design process efficiently expects the use of appropriate tools. Multiple system design tools have been on the market for years. ▷

The possibility of linking device specific tools to the system design tools [11] has not become widely known, because product specific commissioning tools [2] have commonly been used. The roles of the tools are clear – system structure and all communications are designed with system design tools and product specific add-ons can be used for adjusting the device behavior.

The clear distinction between the parameter groups improves the process [4]. Device configuration plugins provide a safe access for control and system experts to the device parameters. The approach follows the standardized CANopen design process and moves the focus from editing the raw values in a set of files to adjusting the system behavior. In addition to system design, standard tools can also be used for system troubleshooting, based on system configuration stored as a CANopen project.

The use of a CANopen tool integration interface provides vendor and version independence between the tools. The tools in the example figures are just examples – the presented concepts are not limited to the example tools. Figure 1 presents how links to the external tools can be defined in EDS files, where the links are automatically copied into DCF files during the system design. System design tool passes a path of the corresponding DCF file as a command line option. The command in an example system design tool is highlighted in Figure 2.

Case A: Encoders

The structure of CANopen encoders is clearly defined and thoroughly organized [14]. Main differences are the most common encoder types – linear, single- and multiturn absolute encoders. All types share the same basic structure with measurement direction control, scaling and preset. Advanced features, such as speed computing and CAMs, are not included in the examples of this article, because they are not supported by the majority of the encoders. The type information is available in the higher word of the device type object [14]. Encoder class information is not available and thus supported options need to be determined based on the objects supported by the encoders. Supported warnings and alarms are clearly indicated in the object dictionary, which helps with troubleshooting. Only the support of commissioning diagnostics control cannot be determined unambiguously from the object dictionary.

The measurement unit of an encoder is the most essential information from the system point of view, because it directly affects control software [6]. Encoder configuration wizards can automatically compute the measuring step size for both signal and parameter objects, based on current scaling parameter values. Currently it is possible to determine the output signal unit by combining information from various objects. But it is not possible to assign measurement unit information directly to the signal and parameter objects, because such an entry is not supported by DCF file format. XDC files supporting unit information can be used in the future, e.g. when tool support has been included [12]. The use of XDC files instead of DCF files enables exporting more complete signal specific meta information into the CANopen abstraction layers of application programmable devices [5].

The user interface of the encoder configuration wizard can be made scalable according to the features supported by a device

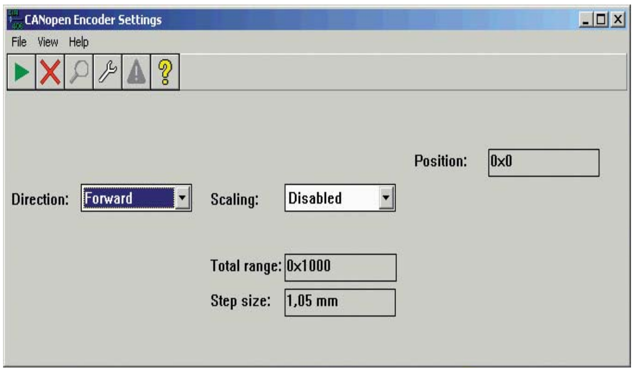

Figure 3: Parameters of a class C1 absolute linear encoder

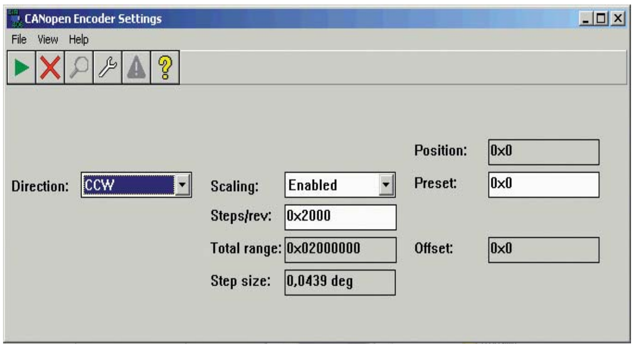

Figure 4: Parameters of a class C2 absolute multiturn encoder

under configuration. Figure 3 presents an example view for a class C1 linear encoder without preset function and with scaling disabled. Measurement direction and scaling selections are presented in human readable form and fields for unused and unsupported parameters are hidden to keep the user interface as simple as possible. The step size has been computed based on the linear encoder measuring step settings.

Another example is shown in Figure 4, where a class C2 multiturn absolute encoder with scaling and preset support is under configuration. Direction enumeration has been changed according to the rotary encoders and supported optional fields are included. The step size has been computed based on the assigned single turn resolution and the number of distinguishable revolutions. Preset value is typically adjusted only by the control system. Position and offset fields are targeted mainly for troubleshooting purposes.

Case B: Generic I/O-devices

Generic I/O-devices are the most typical CANopen devices on the market. The device profile is versatile, which introduces special challenges to the general purpose configuration editors. The basics are straightforward – there are dedicated object areas for digital and analog inputs and outputs [13]. There are also well defined optional control blocks for input and output signals organized so that the sub-indexes match with corresponding signal objects. Supported input and output types are indicated in the higher word of the device type.

A problem can arise in the digital inputs and outputs, which are organized as groups of eight signals. With EDS and DCF files it is possible to identify the number of supported digital channels in multiples of eight signals, not one by one [1] [10]. If the minimum and maximum value of a byte object is defined, the lowest and highest supported ▷

bits can be determined, but possibly unsupported bits between cannot be exactly indicated.

Many devices support multiple analog signal types and ranges, which are controlled by manufacturer-specific objects.

The objects can be linked to the standardized signal objects by using object links [10] to enable generic tools to create complete groups of objects for each channel organized to screen in a logical order. The second problem is exposed, when channel specific physical scaling is needed [6]. There are standardized objects for the description of the physical units, but the effect of scaling objects into the units is not completely defined. The device specific parameter editor could provide such services, but it expects the support of corresponding, object specific meta information entry in configuration files. If signal types are selected by physical connections, e.g. by using type specific pins, systematics cannot be provided by CANopen.

Object links can also be used to define feedback inputs of the outputs. The third problem can be recognized if an output can be either digital or analog. Standardized signal objects can be used and they can be assigned together with object links but a method for describing which one is active is missing. Corresponding objects can be included into the same group by object links, but dependencies of the object values cannot be described in EDS and DCF [10]. The same problem also applies to XDD and XDC files [12].

CANopen valve drivers contain all listed characteristics causing problems for a generic configuration wizard. Therefore the example wizard presented in Figure 5 is device specific. The approach enables including device specific details

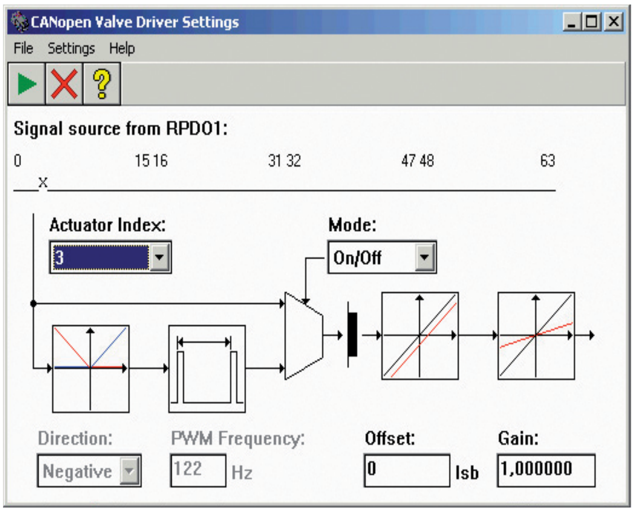

Figure 5: Parameters of a valve driver

into the configuration wizard. In the example devices, operational mode is a complex parameter, which is divided into three fields – actuator index, control mode and direction. Designers will be confused by such complex raw values without using an editor hiding the complexity. The device specific tool also enables an improved screen layout. The block diagram has been adopted from the corresponding device profile with additional device specific blocks. Despite on the parameter organization in the object dictionary, block specific behavior can be clearly visualized. Albeit the configuration wizard is device specific, it does not increase overall complexity because of the standardized tool integration mechanism.

Practical experiences

Based on a few years of testing in various projects, the most significant benefit of CANopen device editors is that the main focus can be on the management of system behavior instead of the raw values and file formats. One consequence is that instead of programming experts, control and system experts – who have the best system level knowledge – can take control over the system behavior. Thus, all errors caused by informal parameter modification requests, invalid raw values and violated file formats can be avoided.

Overall performance will be improved in many ways. Setting parameters becomes much faster and less prone to errors, saving time-consuming troubleshooting and correction of the numerous parameter values. Designers need to spend less time reading the device manuals again and again to find out the correct raw values. Especially with simpler devices, knowing the device profile is often enough. Utilization of the CANopen tool integration minimizes the additional effort caused by the configuration wizard. When they have been installed, after passing the acceptance test, extra work is not required. When only one system tool has network access, only one interface adapter and device driver are needed.

The average speed-up of the parameter assignment phase seems to be as high as 60x, even with very simple devices. Absolute time saving in a design of system with 15 relatively simple devices may be over 2 hours. Half of the speed-up comes from tool integration and another half comes from intuitive user interfaces. The most significant result is indirect – configuration errors and inconsistencies, causing dozens of hours of troubleshooting and repair in assembly and service, can be avoided. All improvements apply to each revision cycle of a project.

Future potential

The concepts presented in this article are based on EDS and DCF files, which will be replaced with improved XDD and XDC files. Using the presented concepts with the new file formats makes no sense, until at least tool integration and emergency error code decoding support are added to the file format. Tool integration support is vital, because it enables all information transfers to and from CANopen projects independently of the tools. Emergency error code decoding improves diagnostics efficiency significantly because the use of multiple languages is already supported [12].

Multiple pictures can be linked to each XDD and XDC file [12]. Several figures are needed for each device, e.g. background images of device configuration editors and component figures as icons for system design and configuration download tools.

More detailed meta information is available for signals and parameters [12]. In addition to the minimum, maximum and default values, value enumerations [7], derived types and units [12] are supported. More detailed data type definitions enable the generation of more complete abstraction layer for application programmable devices. Unit and scaling of signal and parameters may be managed based on DCF files [6], but device editors may improve the unit and scaling management by computing the scaling's based in the device profile specific knowledge. Device editors may also use ▷

device specific knowledge, especially for generic I/O devices. It is impractical to include such functionality in generic conversion or code generation tools. Therefore, XDD/XDC format's natively supporting object units should be completed.

Parameter grouping support provides solutions for two problems that are encountered with generic I/O devices. First, boolean signals can be defined as individual signals and mapped into the object dictionary as groups of eight signals. As a consequence, device editors can detect the exact number of supported digital inputs and outputs, and boolean signals can be provided in the generated abstractions as booleans instead of raw bytes [5]. Second, complex parameters can be defined and mapped into objects as groups of signals with complete enumeration, reducing the need for device specific editors.

Parameter grouping works similarly with EDS and DCF files. The main difference is that in XDD and XDC each signal and parameter has its own unique identifier, based on which the linking works [7] [12]. The identifiers can be utilized by device configuration editors for e.g. improving an automatic screen layout management. However, description of parameter dependencies cannot be included without extensions. ◄

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CAN and Ethernet – similar but different

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Introduction
Ethernet is significantly older than CAN. While Ethernet was invented in 1973 but published in 1976, CAN was created in 1983 and published in 1987. Both networks had the reason for their invention in common: The need for various devices to communicate. This article outlines the differences between CAN and Industrial Ethernet and shows some of the challenges of Industrial Ethernet with some technical background. Furthermore it raises the question: Why switching to Ethernet at all?

CAN and Ethernet have the need for communication in common. Other characteristics are different, for example the kind of devices the networks are used for. From the very beginning CAN was intended to transfer small packets of control data in hard real time, while Ethernet was created to move large amount of data. For Ethernet, being deterministic or real-time was not part of the plan. Common is also their creation as busses. CAN is still a bus, Ethernet not anymore. The switch to twisted pair and star topology as well as the use of multiport bridges made Ethernet even more of a "data lorry".

At first Ethernet shared with CAN the idea of a bus: All nodes were "listening on the same wire", the Yellow Cable or the RG58, the Cheapernet. This topology was limited to 10 Mbit/s. Only Half Duplex communication was possible. Upon transition to 100 Mbit/s the common basics of CAN and Ethernet vanished completely when the Ethernet topology changed to point to point topology with Twisted Pair cables. The Full-Duplex Mode, introduced by the Ethernet Multi Port Bridges, which was called "Switches", took over and the Half Duplex Mode, used by the repeaters, also called "Hubs", disappeared.

In the Half Duplex Mode every network message was seen everywhere in the network. On the face of it this seems to be an advantage, especially considering that Hubs cause a very small delay. Figure 1 shows the typical delay of a hub. The significant effect is that in a Half Duplex network only one node can communicate, while all other nodes are quiet. Every node on the network sees all valid data packets, which is good for Real-Time Control such as it is used in CAN networks, but bad for a "data lorry" network, since other nodes could be communicating during this time.

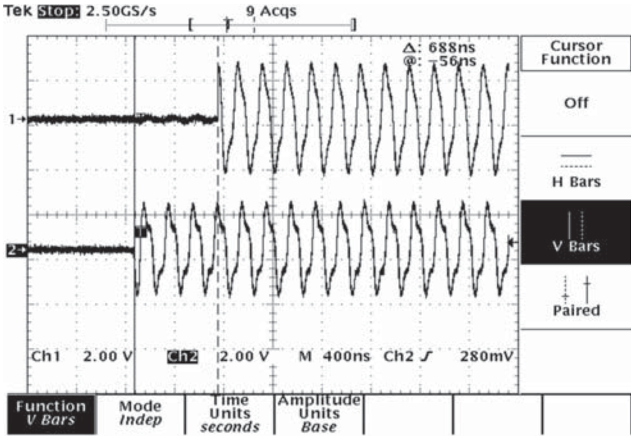


Figure 1: Delay caused by a Hub

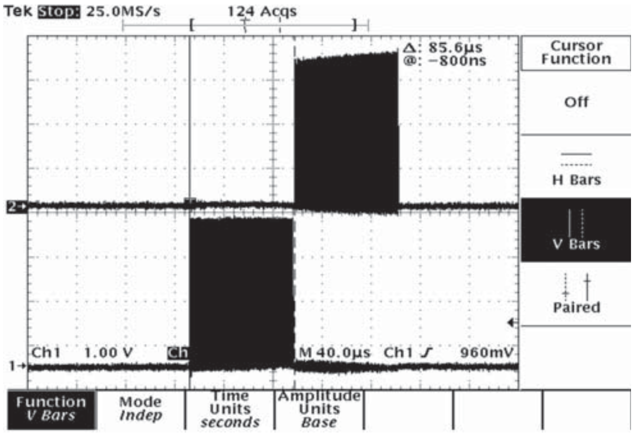


Figure 2: Delay introduced by a Switch (best case)

Full Duplex uses Ethernet Switches, and Switches cause delays by storing packets and sending them out randomly – or not, if something goes wrong. A switched Ethernet network with its highway-like infrastructure provides a perfect base for the Ethernet "data lorries".

The hardware

Connecting CAN to the bus takes little effort: Take a CPU or MCU with on-board CAN controller, some optional optical isolators, a CAN transceiver, and a connector. For software connectivity (e.g. CANopen) a protocol library is needed, in a perfect world coming with a GUI Design ▷

Tool to ease up and speed up the development process.

Connecting Office Ethernet is not significantly more complicated than CAN. The components are similar: Take a PHY (equivalent to the transceiver), an Ethernet transformer (equivalent to the optical isolator) and a RJ45 connector.

Connecting to Industrial Ethernet is not that simple since many aspects need to be taken into consideration. The components are basically the same; however Industrial proof equipment needs to be used. A protocol library with corresponding Design Tools is needed for the software here as well – in a perfect world the libraries would be compatible with other protocol libraries.

Star vs. line structure

Different than CAN, Ethernet is connected in star structure: One single Ethernet port is connected to an Ethernet Switch. For obvious reasons this doesn't always make sense in Industrial Ethernet applications. To accomplish a line structure an Ethernet Switch or Ethernet Hub needs to be built into the unit.

Since nothing is easy when it comes to Industrial Ethernet, specific line structure components need to be incorporated – e.g. a Managed Switch, an extremely low latency Ethernet Hub for Powerlink, an Ethercat slave controller for Ethercat, or a managed Ethernet switch for Profinet and Ethernet/IP.

Powerlink

Powerlink was among the first Industrial Ethernet networks. It adopted the CAN in Automation communication scheme as well as profiles and was considered the CANopen on Ethernet for quite some time. It needs specialized hardware to take advantage of Ethernet's features while maintaining industrial suitability. This hardware is an extremely low latency Hub and a special MAC, which can reply to messages with a dynamic answer in hardware, roughly comparable with CAN's Remote Transmission Request. These components are usually carried by a FPGA. Only in very rare and very specific use cases, standard Ethernet components are suitable. Powerlink claims full management of the network and only grants access to "regular" (TCP/IP) network traffic in the ASND cycle.

Ethercat

Ethercat comes with a completely modified Layer 2, always needing an Ethercat Slave Controller (ESC) – the physical layer component of Ethercat. These ESCs are available by Beckhoff as IP-Cores for FPGA or ASIC component. Some semiconductor manufacturers have integrated ESCs in their CPU/ MCU designs. Ethercat claims full access to the network as well and allows for "regular" (TCP/IP) network traffic with the EoE (Ethernet over EtherCAT) mailbox protocol.

Profinet and Ethernet/IP

Different than Ethercat and Powerlink, Profinet and Ethernet/IP work with standard components only except for Profinet IRT. Both protocols can be integrated in standard network environments and are able to use existing network stacks (e.g. TCP/IP Stacks). While Ethernet/IP uses only regular UDP/TCP communication, Profinet uses a proprietary scheme for real time data. Both protocols represent the most significant market share.

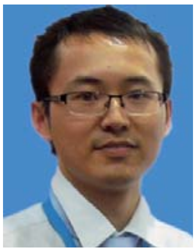
Conclusion

Application requirements can sway the decision in favor of Ethernet or CAN. While CAN is designed for Industrial Automation, Ethernet is made ready for Industrial Automation. Both work fine, however they are based on different paradigms. ◀

CANopen for Chinese product quality

Longfeng Gong

Author



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More and more system designers and system integrators in China focus on CANopen. High reliability, real-time capability, low-cost, fault-tolerance and compatibility are key components of CANopen. To extend CANopen concepts and support more efficient CANopen systems in China, Hongke Technology makes every effort to help Chinese system designers integrate their own CANopen applications. Because they can take advantage of a mature and reliable CANopen source code, developers can save time and money. By using the CANopen Protocol Stack Source Code by the German company Sys Tec Electronic, Hongke Technology helps spreading CANopen in the Chinese market.

In China, Hongke Technology has managed to help engineers in developing servo drives and controllers, motion controller cards, medical equipment, sensors, encoders, door control systems, laser systems, mining controllers, HVAC control systems and more - all based on CANopen communication.

A lot of these products are already available off the shelf. For complicated tasks, the company also provides an OEM porting service. The motion controller card serves the production quality inspection of newly manufactured motors in testing different operating functions.

The controller takes charge of managing and testing eight servo drives. It works as a CANopen master and features two CAN ports for a CANopen interface. The CANopen source code used in the motion controller card and in the testing platform is modular. The testing platform is based on a TI AM335x ARM Cortex-A8 running an RTLinux operating system.

The CANopen source code implements the complete functionality according with the CiA 301 specification and it supports the standard compliant design of fully-featured CANopen master or slave devices. The structure is scalable and portable. Written entirely in Ansi-C, the source code allows custom tailoring of the stack to every application. The continuous modularization of functionalities and implementation in Ansi-C makes porting to different target systems possible. Great importance was set on scalability and performance. Sys Tec Electronic provides a most convenient environment for development, integration and testing of CANopen applications.

With the benefit of the modular, scalable and portable structure of the CANopen source code, the motion controller card builds a modular structure with four layers. The first layer is the Development Environment CAN driver software, provided by the AM335x ARM Cortex-A8. The second layer is the CANopen protocol stack layer, based on the CANopen source code framework, including CANopen standard communication protocols, PDO, SDO, NMT, SYNC, etc. The layer transforms the CAN signal of the master controller into a CANopen protocol. The third layer is the CCM layer, which achieves the CCM main function. It provides the function interface of CANopen read/write, the packaging of API, and predefines the object dictionary of application object parameters. The fourth layer is the application layer. The servo drive responses to the call of the CCM main functions and implements the servo motion project according to different testing scenarios.

The key point of this project is an integrated development process. It can be integrated successfully thanks to the experience of Sys Tec Electronic in hardware system integration with Linux. The well-defined API allows for an easy use of the CANopen services without diving into details of the implementation. Additionally, the example programs target specific demo projects, and the comprehensive documentation assists the complete project step-by-step.

Currently, many similar CANopen development projects can be found in China, which not only brings the German state-of-the-art CANopen technology to China but also allows developers to constantly absorb the essence of advanced technology. Thanks to this cooperation, new CANopen applications will bring vitality to the potential Chinese market. ◀

Electric servo drives prove themselves in outdoor use

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There are many cost-effective ways of using electric drive technology in agricultural and construction machinery. Thanks to this technology, process control and thus productivity are increased due to greater efficiency of the electric drive technology. Recuperation of kinetic energy and mechanical speed decoupling of the combustion engine enables fuel to be saved, which in return protects the environment. With its double inverter JMM-5000, Jetter has extended its product range for the automation and electrification of agricultural and construction machinery. The company's more than thirty years of experience in industrial applications also benefits mobile automation.

The double inverter, which is designed as a four-quadrant inverter, can be integrated into the overall system. It can be powered with an AC or DC supply. For self-propelling harvesting or construction machinery, the double inverter can also be provided with a DC/DC output, so that the vehicle can be supplied with 12 V_{DC} or 24 V_{DC} and up to 400 A straight from the vehicle battery. The inverter is available with power ratings from 5 kW to 80 kW and is used as a wheel or ancillary drive.

It is stackable - i.e. the inverters can be installed one above the other, because all power, control and water connections are located on one side.

The JMM-5000 was used in the field for the first time in the middle of 2012 and has therefore already proven its suitability for use in harsh environments.

The efficiency of electric drive systems is, alongside numerous other factors, heavily dependent upon how long the machine is used. If the machine is not used for very long, the process improvement must predominate in order to justify electrification. Improved process control means fewer downtimes, optimal filling of the machine, exact feed length that is optimal for fodder use (e.g. for biogas plants, as fodder, etc.), low-loss harvesting of the fodder, etc. The speed decoupler allows each drive to run independently of the speed of the combustion engine, enabling it to be operated and held at its most fuel-efficient point.

An energy management system tailored to the machine ensures energy distribution. For example, if kinetic energy is recuperated, the energy management system ensures that this energy is stored or used elsewhere in the machine. In this way, the load and speed of the combustion engine is kept constant and energy is saved.

This stored energy can be used for boosting, i.e. at times of peak loads, so that the combustion engine is held at its optimum consumption point.

The swivel drive on an excavator is an example. The excavator fills its shovel in the loading process, swivels it towards the dumper or truck and tips the contents out in the unloading process.

In doing so, the structure must be accelerated and then decelerated after approx. imately 90°. This braking energy is recuperated/stored in the process and used for acceleration. This reduces the energy required by the swivel drive by about 50 %.

Wheel drive on a potato harvester

In this application, the energy is generated by a PTO (power take-off) and passed ▷

Summary
Electric drive technology has established itself in industrial automation. Mobile automation hasn't. When it comes to controlled drives for mobile machines, this industry used to rely on hydraulic systems. There is a great number of mobile implements and vehicles though for which the application of electric drive technology is a good idea. Jetter AG now brings the double inverter JMM-5000 (JetMove Mobile 5000) to the market, especially for such applications. It fulfills the particularly high requirements for outdoor use with regard to temperature, seal, vibration, dirt and moisture protection.

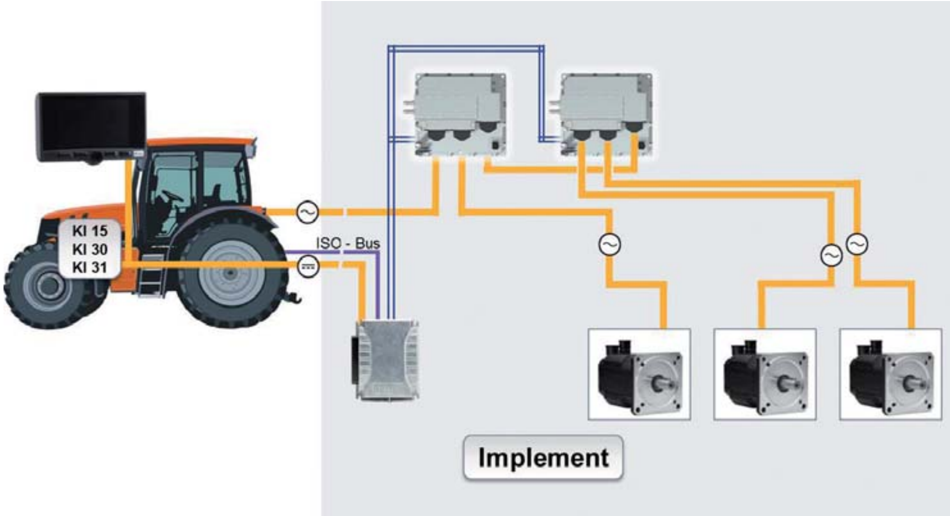

Figure 1: Example configuration of JMM-5000 with a DC supply

to the implement via a specially designed connector. The PTO is driven via the front PTO shaft of the tractor. The VDC generated by the PTO is stored in the DC link of the double inverter and passed to two permanently excited synchronous motors. It was specially designed for this application by Jetter and has a high power density.

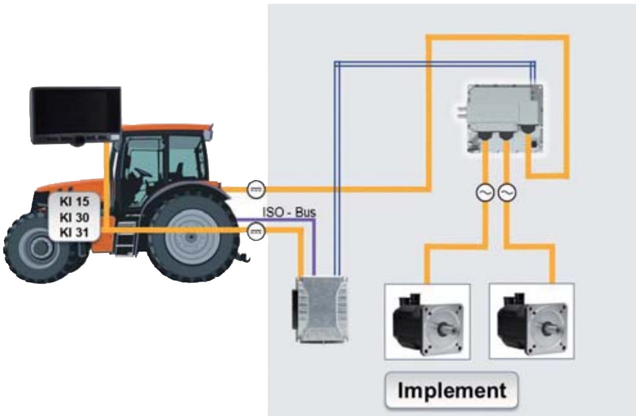

Figure 2: Example configuration of JMM-5000 with an AC supply

The software implemented in the double inverter controls the speed, so that the implement runs synchronously with the tractor. It also monitors the power and torque to avoid the creation of any extended overloads (the double inverter can be overloaded to 150 % for short periods) and prevents the wheels from "slipping" in poor surface conditions.

A resolver is used to monitor the motor speed. The temperature of the motor is monitored by thermocouples. Thanks to its high power density, the 30 kg motor delivers 27,5 kW to each wheel. The implement is therefore driven via both wheels with 55 kW. The planetary gear unit used has a transmission ratio of 1:65 and can be switched off while moving the implement from one site to another.

Winder unit of a round baler

Just like in the potato harvester, the electrical energy is generated with a PTO. Important for the potato harvester is the improvement in the energy balance. In the winder application, on the other hand, the focus is on improving the process, because the viscosity of the film changes depending on different weather conditions and the different film types used for round bales.

This can be done more easily with electric drives, which can be more finely controlled, than with hydraulic drives. In electric drives, the torque is detected via the current that flows to the motor and is set and monitored to prevent the film from tearing. If the torque changes, the baler can be brought to an immediate stop within 450 milliseconds, avoiding any tears in the film. This saves valuable downtime.

"Saving energy has to go hand in hand with increasing efficiency", which all companies have realized by now. In the field of drive technology in particular, a high amount of potential exists in this direction. Experiences from the area of industrial automation will only continue to help in the area of mobile automation to a limited extent, as the conditions for outdoor use are mostly completely different. ◀

Figure 3: Schematic of a winding unit on a round bale press

Control panels use off-the-shelf CANopen components

Introduction
Switches from Schlegel Elektrokontakt are used in all kinds of machines, in lifts, ships, and special-purpose vehicles. Additionally, the company configures control panels according to customer requirements. For control panels connected via a CANopen interface or other industrial communication protocols, Schlegel uses Deutschmann Automation's ready-to-install Unigate IC bus nodes.
At its headquarters in Dürmentingen, Germany, Schlegel has been developing and manufacturing control units, signal lamps, and terminal blocks for more than 60 years. Membrane and short stroke keyboards, enclosures, limit switches, control panels, and function blocks have also been part of the product portfolio for a long time. The products are primarily used in machine tools, test rigs, instrument panels for lifts, ships and special-purpose vehicles. However, they are not limited to industrial applications: The company's products ensure reliable switching in any location, e.g. in control panels of public swimming pools, department stores, or office buildings.

Since control panels are used in a wide range of applications for various purposes, they must fulfill different requirements concerning form factor, integrated control units, and interfaces to connect them to controllers. By adopting a modular approach for all operating solutions, Schlegel provides and designes panels that fit into their surroundings even in small quantities. Thus, customers can choose the material, shape, and size of the panel, and can also have them labeled and engraved in their corporate design. The company equips the control panels with standard contact elements or with Industrial Ethernet or serial bus system communication interfaces as required.

Figure 1: Control panel from Schlegel

Serial bus system equipment

Operating solutions with a serial bus system or Industrial Ethernet interface are mainly used when a large number of control and signaling devices must be connected with minimal wiring effort. Schlegel offers modular control panels and keypads with CANopen interfaces and other industrial communication systems. A carrier board is configured according to the customer-specific design of the complete solution, located behind the front panel, which houses the control units. The carrier board is populated with contactors for the control units and physical interfaces for the desired network. If required, the manufacturer also adds I/O interfaces, allowing for peripheral sensors to be connected to the network or the controller via the control panel. Moreover, the carrier board contains a socket to connect the network module, which organizes all data traffic between the ▷

CANopen gateway program

With the ready-to-install, all-in-one Unigate IC CANopen network nodes, the Unigate CL CANopen protocol converters, and the Unigate CX modules that are interoperable with CANopen, Deutschmann provides gateway solutions for applications. They allow users to equip new units with CANopen interfaces and to connect existing devices without a suitable interface. In order to connect AS-i devices and networks in CANopen environments, the company also offers the Unigate AS-i module, which features an AS-i master board with the M-4 profile and fulfills the AS-Interface Power24V specification. CANopen gateways from the CX series connect all types of automation networks with CANopen networks. With their modular design based on two CL units, the DIN rail devices are available for all serial bus systems and Ethernet variants with CL devices. In all Unigate series, a script converts the protocol of the terminal device or the network protocol, thus enabling adaptation to CANopen requirements. By default, the devices are delivered with scripts for transparent data transfer. The free-of-charge PC tool, which requires no special programming or CANopen knowledge, can be used to create customer-specific scripts.

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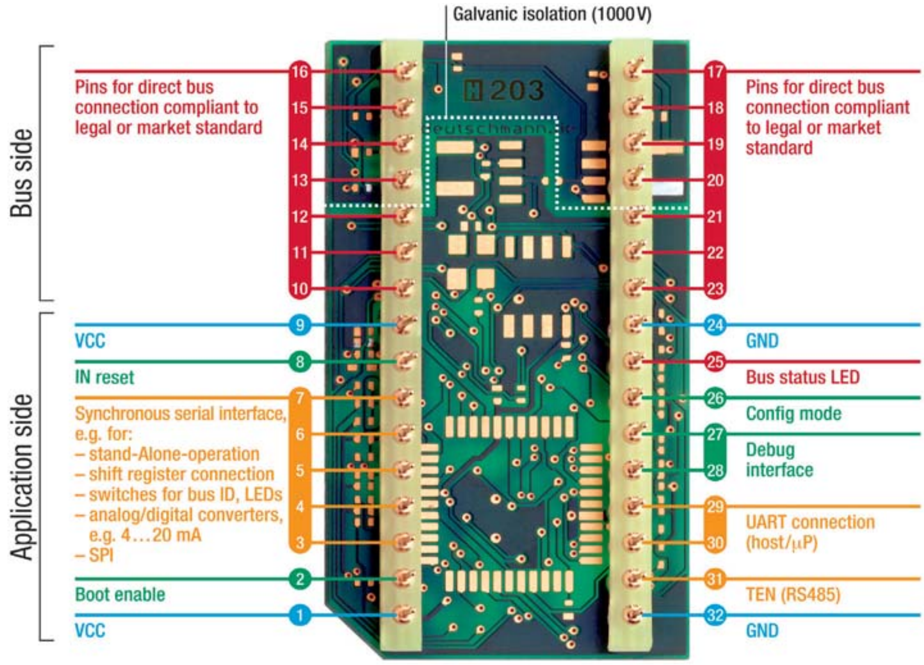

Figure 2: Unigate IC standardized pin assignment

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control panel and the controller through the CANopen protocol. For these network modules, Schlegel uses Deutschmann Automation's ready-to-install Unigate IC network nodes.

Economic factor

"Primarily, we are a manufacturer of control units, terminal blocks, and signal lamps", explained Georg Selig, Project Manager at Schlegel. "Developing serial bus system components is a separate field that requires specific know-how and considerable additional efforts for maintenance, documentation, and certifications." Therefore, Schlegel chose an economically viable solution, cooperating with an external network module specialist who has relevant experience and know-how. "Using Deutschmann's Unigate IC interfaces, we are no longer faced with the costly efforts of proprietary developments", said Selig. "Especially small to medium quantities, which we often deal with when producing customer-specific operating solutions, benefit from using Deutschmann products compared with developing our own solution. This way, we can supply our customers with mature products within a very short time and at an attractive price. Thanks to the interfaces, we can present the prototype of an operating solution merely three days after receiving an order."

The fact that Schlegel no longer needs staff to maintain and update the network module software is another advantage of the cooperation with Deutschmann: since Deutschmann constantly adapts the nodes to current network-specific standards and requirements, Schlegel's solutions automatically remain up to date.

Multiprotocol solution

Featuring hardware and software interfaces with the same standardized functionalities, Unigate ICs enable the implementation of multiprotocol solutions. Manufacturers merely need to integrate the adaptation board, which holds a socket for the nodes or implement a socket directly on the device board. Thereby, Schlegel can, for instance, offer an operating solution for various protocol types. They are based on a carrier plate design, e.g. adapting a carrier plate with Ethernet connections for a ▷

Unigate IC

Unigate ICs are complete, ready-to-install network nodes that combine a microcontroller, Flash, RAM, and a network controller on a 45 mm x 25 mm footprint in a 32 DIL housing. The miniature interfaces handle the complete communication on the network side, thus significantly relieving the application's microprocessor. The devices are connected to the host processor via a UART interface. In addition to CANopen, the series also covers all standard serial bus systems, Industrial Ethernet protocols and building automation systems such as LonWorks and BACnet/IP. Deutschmann also offers variants with EIA-232 or EIA-485 interfaces for RS-based protocols like Modbus RTU and Modbus ASCII.

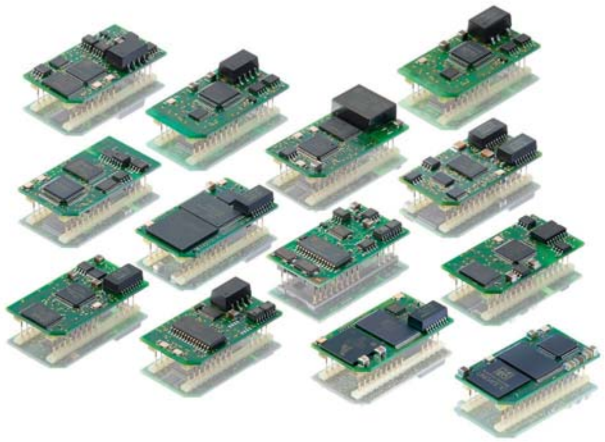

Figure 3: The ready-to-install network nodes are available for all standard Industrial Ethernet variants and serial bus systems

Figure 4: The Unigate CANopen range includes AS-i-CANopen, CX, the integrated IC CANopen type (front), and CL CANopen (from left to right)

different Ethernet standard by simply exchanging the network module for another model.

Protocol conversion via a script

Schlegel chose this network node for a variety of reasons. "In the end, the key factor for our decision was that Unigate ICs can be easily adapted to the protocol of our devices via a script. We therefore no longer need to make laborious changes to our firmware", said Selig. The concise, C++-based script language, which can be programmed by means of the free-of-charge Protocol Developer Windows tool, enables users to emulate applications as well as buffer and further process data. The script also allows for the integration of customer-specific commands, for linking actions with time and event-based triggers, and for displaying all data and statuses within the network. Since the compiled code comprises only a small amount of data and Unigate ICs feature a large script memory, even extensive scripts can be stored. The Protocol Developer tool features functions for debugging of large-scale scripts, such as breakpoint, single-step, display of variables and their values as well as error display. Since the series features standardized hardware interfaces, generated scripts can be used for all serial bus systems and Ethernet-based models of the series. ◀

2nd generation safety controller for mobile applications

Alexander Holler, Hans-Dieter Kaiser

Introduction
The safety requirements defined in EN ISO 13849 are getting more and more relevant in the mobile machinery market. When comparing the requirements in dedicated C-level standards for different mobile machines, it appears that Performance Level d (PL-d) is mainly demanded for controllers to achieve sufficient functional safety. Not all C-level standards demand to meet the safety requirements set forth in the EN ISO 13849 today. But when developing a new machine with a life cycle of 5 to 10 years, the consideration of functional safety is inevitable. Beyond the performance level, additional features of a safety controller help increase the sustainability and flexibility of the machine's control system.

The processing power of a safety PLC is not only defined by its processor's speed but also by its architecture. To address the safety requirements in controller architectures two principles are usual:

Firstly, the architecture could be realized as a category 2 system according to IEC 13849; the logic unit (main processor) in that case is supervised by a test unit (companion). This category 2 architecture demands significant processor resources for self-test and thus limits the capacity available for the functionality itself. Furthermore specific C-level standards like the EN 280 do not permit dedicated safety functions in category 2.

Secondly, category 3 architectures are built with two discrete main processors. This offers higher performance but at higher costs than category 2 systems. In addition, two application programs, one for each logic (main processor), are required, which imposes a higher work load on the programmer.

To avoid the inconvenient handling of two application programs as well as the costs of a discrete category 3 system on the one hand side and to take advantage of the higher performance of the two main processors, the safety controller digsy fusion S is based on a dual core safety processor as shown in Figure 1. The dual core safety processor integrates the two logics and is therefore able to manage the distribution of the application program on the two cores internally. The processing of the application program is done on both processors in parallel step by step. A step in this connection is the smallest possible processor operation, consisting of reading and processing data and writing results. Finally, the results of both cores are compared. As the operation of both cores is locked together, this procedure is called lock step mode.

Figure 2: Safety controller digsy fusion S

For demanding applications it might be necessary to perform complex operations like trigonometric calculations. In this case FPU's (floating point units) are the appropriate processing platform to assure reasonable calculation time. While the supervision of FPU operations in category 2 architectures is not feasible, dual core processors provide the means to meet safety requirements without overload of internal self-tests.

CAT.3 or CAT.2 control systems

Even if a safety controller has an internal category 3 architecture, it may also be integrated in category 2 machine control systems. The digsy fusion S safety controller for example is able to communicate with safety sensors in two ways: either as a redundant or as a single channel connection, depending on the required safety level and the design of the sensor. Due to the still limited number of safety sensors available on the market it is useful to have the opportunity to choose between both options – provided the required safety level can be achieved in both ways. Controllers do not inherently provide the option to connect safety sensors with just one channel. To support this single channel connection, the input of the controller needs to have internal diagnosis to assure the demanded diagnostic coverage. If this is available, safety sensors could be connected with a single channel connection as shown in Figure 2. Alternatively, redundant sensors or two sensors providing redundant signals could be connected to the same safety controller as shown in Figure 3.

This solution is typically implemented when the ▷

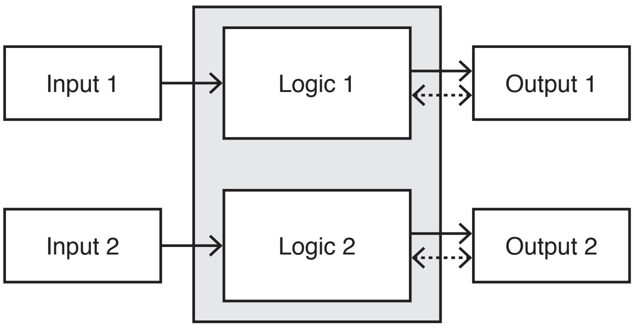

Figure 1: Category 3 architecture / integrated

relevant safety standards demand it or if category 2 sensors are not available. As the safety controller supports connecting category 2 and category 3 sensors, it provides the flexibility to select the sensor by its performance and not by its interface.

Standard and safe communication

In terms of field busses CAN is the standard protocol in mobile machinery. The digsy fusion S offers four CAN interfaces. Each provides different protocols, as they are CANopen and J1939. Layer 2 programming serves as a way to achieve any other desired protocol. CANopen is widely used in mobile automation. Many components, i. e. sensors and actors, are available on the market, using this standard and meeting the requirements for industrial and mobile applications. CANopen offers all basic protocol functionalities as a defined system start up, network management, system data exchange, process data exchange, synchronization and emergency messaging. The required configuration of CANopen communication is performed using the standard programming tool of the safety controller. If functional safe communication via CAN is required, CANopen Safety standard (EN 50325-5) is recommended. It is a protocol extension of CANopen and provides a safe communication between two or more CAN network members.

Safe communication is achieved through Safety Related Data Objects (SRDO). SRDOs have to be transmitted periodically within a Safeguard Cycle Time (SCT). A SRDO consists of two CAN communication objects (COB) CAN1 and CAN2 that have to be transmitted within the Safety Related Validation Time (SRVT). The two COBs differ in COB-Identifier (COB-ID) – min. 2 bit – and in normal (CAN1), respectively bitwise inverted (CAN2) payload. If a receiving node detects expired SCT or SRVT cycles or differences after comparing the payloads of CAN1 and CAN2, it will enter safe state. Thus, a safe communication is guaranteed that meets the requirements of the EN 61784-3 standard regarding message corruption, unintended repetition, incorrect sequence, message loss, message insertion, masquerade and addressing.

Flexible changes of the application program

The long life cycle of mobile machines often requires adapting their functionality to changing market requirements. Digsy fusion S supports this through the ability of running two projects in parallel. The first project (safe project) is responsible for safe machine functions, while the second project (standard project) takes care of all non-safety related functions like comfort functions. As the standard project can not interfere with the safe project, it is

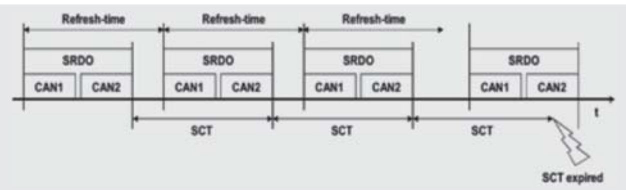

Figure 5: CANopen Safety – Safeguard Cycle Time

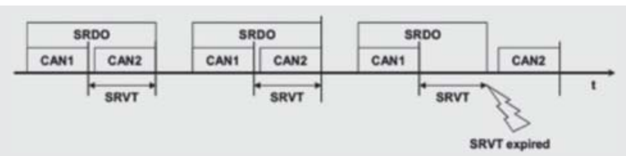

Figure 6: CANopen Safety – Safety Related Validation Time

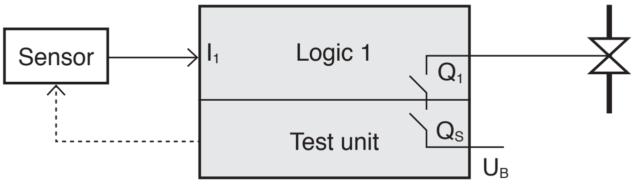

Figure 3: Single channel connection, typical for category 2 architectures

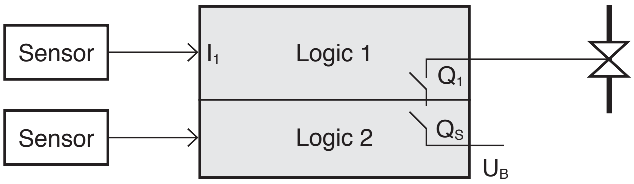

Figure 4: Redundant connection, typical for category 3 architectures

possible to change the standard project without an additional safety analysis. The safety controller utilizes Codesys 3.5 SIL2 for running the safe and the standard project, thus it is ensured that just one consistent programming environment is necessary.

Increased uptime

Monitoring the machines functionality regarding dangerous conditions is one of the core tasks of a safety controller. Once a dangerous condition is detected the machine is set in failsafe state by the safety controller. This is done by activating a second cut off path which de-energizes the outputs. Depending on the kind of failure causing the dangerous condition it may be necessary to shut down the complete machine. But not all failures must cause a complete shutdown. A safety analysis may lead to the result that a failure in one function does not have to automatically result in a shutdown of other machine functions. In this case it is useful to keep the functions unrelated to the failure alive to allow e.g. the recovering of the machine or complete the last maneuver. For this reason the safety controller provides four groups of second cut off paths. This enables the user to just shut down the outputs that are related to the dangerous condition. Other functions can be kept alive even in case of a failsafe. ◀

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Resumee
Performance, functionality and conformity with the relevant safety standards do not exclude each other. 2nd generation safety controllers that achieve PL-d according to EN ISO 13849 provide the necessary features.

From motor control to system monitoring

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Introduction

Perfectly tuned power transmission is one of the key factors in modern day racing sports. A racing team at the university of Siegen, Germany has developed a new electric racing car. With a CANopen master interface from Hilscher they connected the various sensors of the vehicle to the engine control system.

The "Formula Student" is an international car racing competition where student teams compete with self-developed vehicles. In this competition, the success of a team does not only depend on the performance of the vehicle itself, but also on criteria, such as engineering, marketability and production costs.

The Speeding Scientists Siegen is one of these racing teams. After successful participation with conventional vehicles during the 2009 and 2010 race season, the team developed for the first time an electrically power car to participate in the Formula Student Electric for the 2011 season. System automation specialist Hilscher from Hattersheim, Germany, accompanied the team during the development of the racing car and contributed interface cards for its electronic control system.

Detecting and reacting

One vital factor for the ability of a racing car to transfer the energy of its engine to the street is an efficient drive control system. However, such a system depends on comprehensive information, which is provided by numerous sensors and transferred to the engine control system in a form ready for processing.

For this purpose, the racing car Se-12e designed by the Speeding Scientists Siegen features an engine control system communicating with a high-performance sensor control system.

Figure 1: During a practice run

Primary function of the sensor control system is to receive the analog information provided by the various sensors of the vehicle and transform it in a digital format in real-time. This includes the exclusion of illogical values as well as the detection of defective sensors.

Data communication between the sensor system and the engine control system takes place via the CAN network (version 2.0A in layer 2 mode), which is the standard data network in the automotive field.

"Mediator" between protocols

A suitable interface card was required to transmit the telegrams of the sensor system via the CAN network to the engine control system. Hilscher provided the team with its CIFX 104 CANopen master interface. It comes in the form factor of an interface card and is available with a variety of interfaces. The CANopen module of this card is able to also process layer 2 communication.

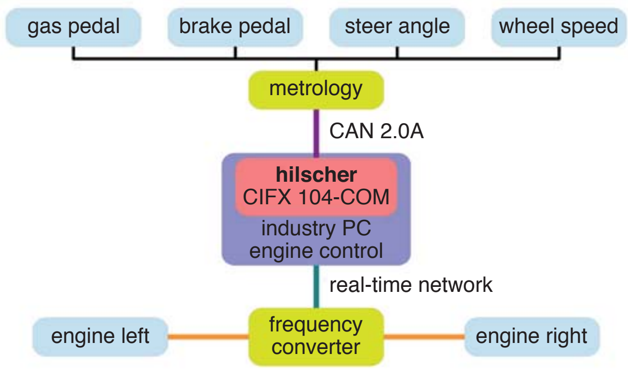

Figure 2: The system's architecture

Figure 3: On the speedway

Figure 4: The S3-12e

One special advantage of the interface card for the race car S3-12e, was the fact that its drivers allowed seamless integration of the data stream into the engine control software running on a standard industry PC. Additional advantages were the highly robust design of the interface card as well as its high resistance against electromagnetic interferences. After all, the car was based upon a low-weight design, which required to exchange the standard metal enclosure of the interface card by an especially designed ultra low weight enclosure made of carbon fiber.

Successful interaction

Thanks to the CANopen master interface, the racing team was able to realize seamless interaction between the sensor system and the drive control system of its race car. The cooperation between Hilscher and the Speeding Scientists Siegen also proved to be successful.

At the Formula Student Germany 2011, which took place at the Hockenheim race track in Germany, the team was able to reach in the 17th place. Unfortunately, due to a technical defect of the break system, this position could not be topped anymore during the season. But the team used the test runs for further optimization of the vehicle.

As a result, the S3-12e was able to reach the 4th position at the Formula Student Spain, which took place at the Circuit de Catalunya in Barcelona. This was the best position the Speeding Scientists Siegen had ever reached since their participation in the Formula Student.

After all, success is usually the result of experts getting together and the right people forming a team. ◄

Motor selection: Optimizing belt drives

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Conveyor systems with CAN network are becoming ever more popular. The reason is the flexibility and simple controllability of several drives, which the network system provides. It is expected that the systems can be flexibly adapted to a certain extent, whether in terms of speed or the loads that are to be transported. This also applies to the choice of drive.

In conveyors for simultaneous inspections or pick-and-place applications, for instance, it must be possible to exactly move to precise positions. Only a drive that knows its precise position can be considered for this purpose. Flexible speeds are another point that appears on the wish list from time to time in terms of a flexible construction design.

The selection of possible drives is equally diverse: AC motors, BLDC motors or stepper motors operated in closed loop configurations that behave like multipole servo motors – all of them are worth considering. The crucial factors in the choice of a suitable motor type are the speeds required, the demand for networking and the desired flexibility of the process.

We take a look at a classic example, where a weight is transported at a predefined speed by a conveyor belt. For example, if the belt is 4 m in length and has a roller diameter of 6 cm to transport a part load of 10 kg x 2 kg at a desired speed of 0,6 m/s, i.e. approx. 191 rpm, a drive with a torque rating of 2,8 Nm is required. Here 0,8 Nm is factored in for an acceleration speed of 0,7 s.

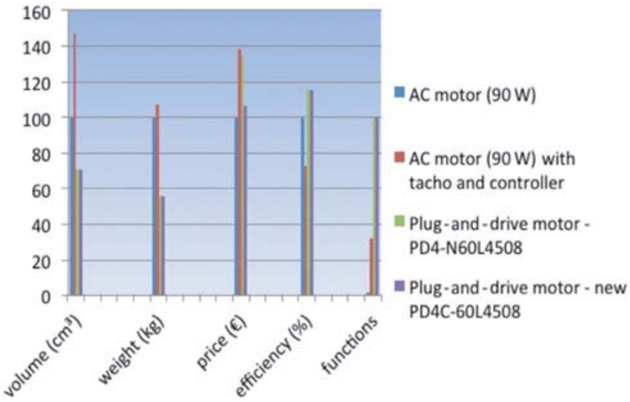

Figure 1: Comparison table of AC motor and plug-and-drive stepper motor

A suitable asynchronous motor (AC motor) would need a capacity of at least 60 W in this case. With a construction volume of 90 mm in diameter and 185 mm in length, including spur gearing of 7,5:1, this motor would have a total weight of 4,3 kg. AC motors require constant speeds. If a different speed is required due to the process flow, either a new drive unit must be installed or, at best, the gear replaced. If flexible processes are called for, the situation might not be so fortunate.

Plug-and-drive motors based on stepper motors are more flexible. With a size of 60 mm x 122 mm and a weight of 1,5 kg, a model tailored to the above example is significantly smaller and lighter than the AC motor plus gear variant. Plug-and-drive motors are stepper motors that already have the controller and the encoder integrated in the housing. This makes them especially compact, and easy to install and control. Only the power supply and the network still need to be connected. Plug-and-drive motors therefore correspond to the fundamental CAN notion of a simple, decentralized design. They can be integrated in conveyor rolls or rollers to form highly integrated transport units and can also be used as switching points in conveyor systems. At a nominal speed or half speed, tests with a belt conveyor demonstrate an efficiency of 60 % or 45 % compared to 52 %, respectively 30 % with an AC motor. For smaller conveyor belts with a load of 2 kg to 3 kg, the size of the AC motor normally needs to be 60 mm (weight 1,6 kg); if a plug-and-drive motor is used, a size of 42 mm, which weighs just 0,4 kg, is sufficient.

Field-oriented controlled stepper motors behave like multipole servomotors. In addition, in most cases ▷

they do not need any gearing because of the high torque in relation to speed. Only for high transport loads and very low speeds can a gear be necessary. Another point worthy of consideration is the efficiency. Whereas asynchronous motors (AC motors) build up a magnetic field in the rotor through the induced alternating field, synchronous motors, such as stepper motors or BLDC motors, have a permanent magnet in the rotor and thus at nominal speed have an efficiency factor ratio of 60 % to 80 %.

The high efficiency of AC motors applies only to the bare motor, however. As part of new machinery directives, AC motors must be equipped with soft starters or standstill and speed monitoring. This reduces efficiency. As for speed control, it is favorable to use an AC motor plus tachometer, which allows a speed range of approximately 15:1 via a control unit. This method is also favored if the speed required has not been exactly determined at the start of the project. The often-used voltage/frequency controller causes higher losses in the driver at lower speeds. Commendable efficiencies of approximately 60 % in AC motors are not far off: the spur gear already absorbs 18 % anyway and the driver decreases the power output even further. At speeds lower than the nominal speed, the efficiency of an AC motor can easily drop to less than 30 %.

Stepper motors only make sense as belt drives, however, if they are operated as multipole servos in a closed loop. The required load current is adjusted by the control loop and allows the drive to respond flexibly to changing conditions. Less heat is lost in the motor due to the efficient current control. It remains considerably cooler, which

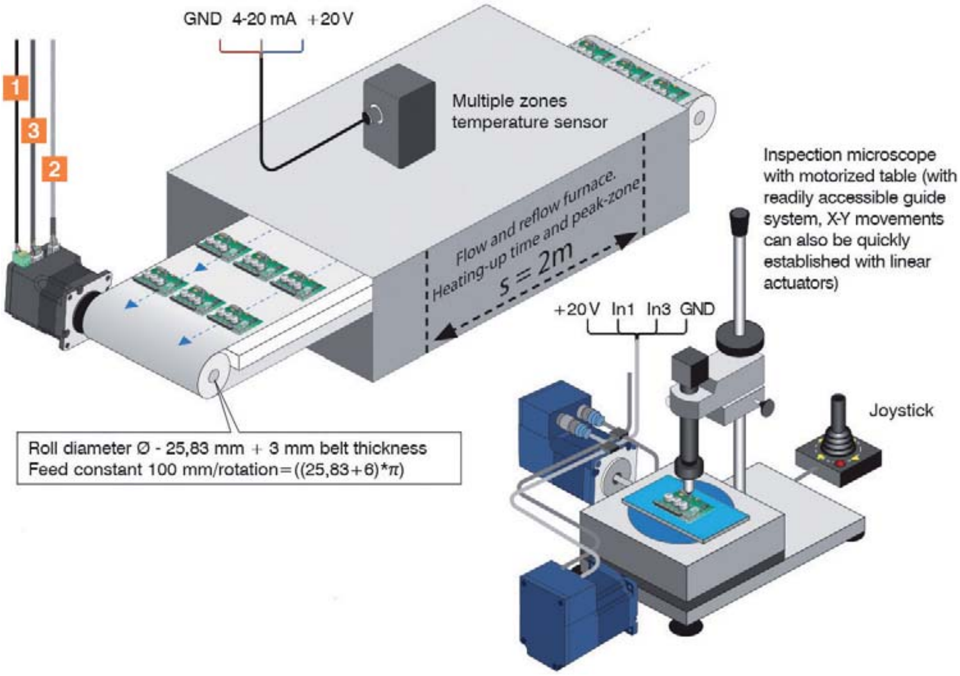

Figure 2: Synchronization properties mean better processes or precision can be achieved, even in the lower speed range; in the soldering example synchronization properties mean the soldering time can be maintained exactly; varying soldering times impair the soldering quality, and hence the long-term contacting

protects the motor bearings. The plug-and-drive motors contain a high-performance microprocessor that not only provides the field-oriented control and controls the integrated power output stage, but also monitoring functions, e.g. for diagnosing overload, blockage etc. Higher-level movement states can be queried via the inputs/outputs, logically linked and further processed in the network via CANopen.

For straightforward set up and installation independent of the CAN master, the NanoCAN Window software, which is used to read and set all SDOs as well as to test runs in the various modes without programming knowledge, is available for Nanotec motor controllers and plug-and-drive motors. Whether the motor is operated in open or closed loop, can also be configured by manufacturer-specific CAN objects.

The ideal operating range of closed loop-driven plug-and-drive motors ranges from 100 rpm to 800 rpm, depending on the motor type, and can be varied in the speed range of 25:1. If higher speeds are needed with the same size and load, brushless DC motors (BLDC) are recommended. These low-pole motors are mainly designed for higher speeds (> 3000 rpm), but have much greater efficiency than AC motors. The only drawback: They also need a gear. But their efficiency is superior to AC motors. For the same transport task (20 kg load + 5 kg belt), a feed speed of 1,5 m/s (500 rpm) can be achieved with a BLDC motor of 56 mm x 236 mm in size, including gear. These motors require external motor controllers such as the SMCI36, which also has a field-oriented control and can also control stepper motors. A CAN slave is integrated in the same way as in plug-and-drive motors.

AC motors are reliable drives if the power requirements are constant and if size and energy efficiency are irrelevant. But as soon as value is placed on flexibility, BLDC motors – such as plug-and-drive stepper motors acting as multipole servos – are recommended for the lower speed range or at speeds above 3000 rpm. Normal stepper motors, in contrast, are not an alternative. They work in open loop, so deviations and false positioning cannot be detected. ◀

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