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CAN Newsletter

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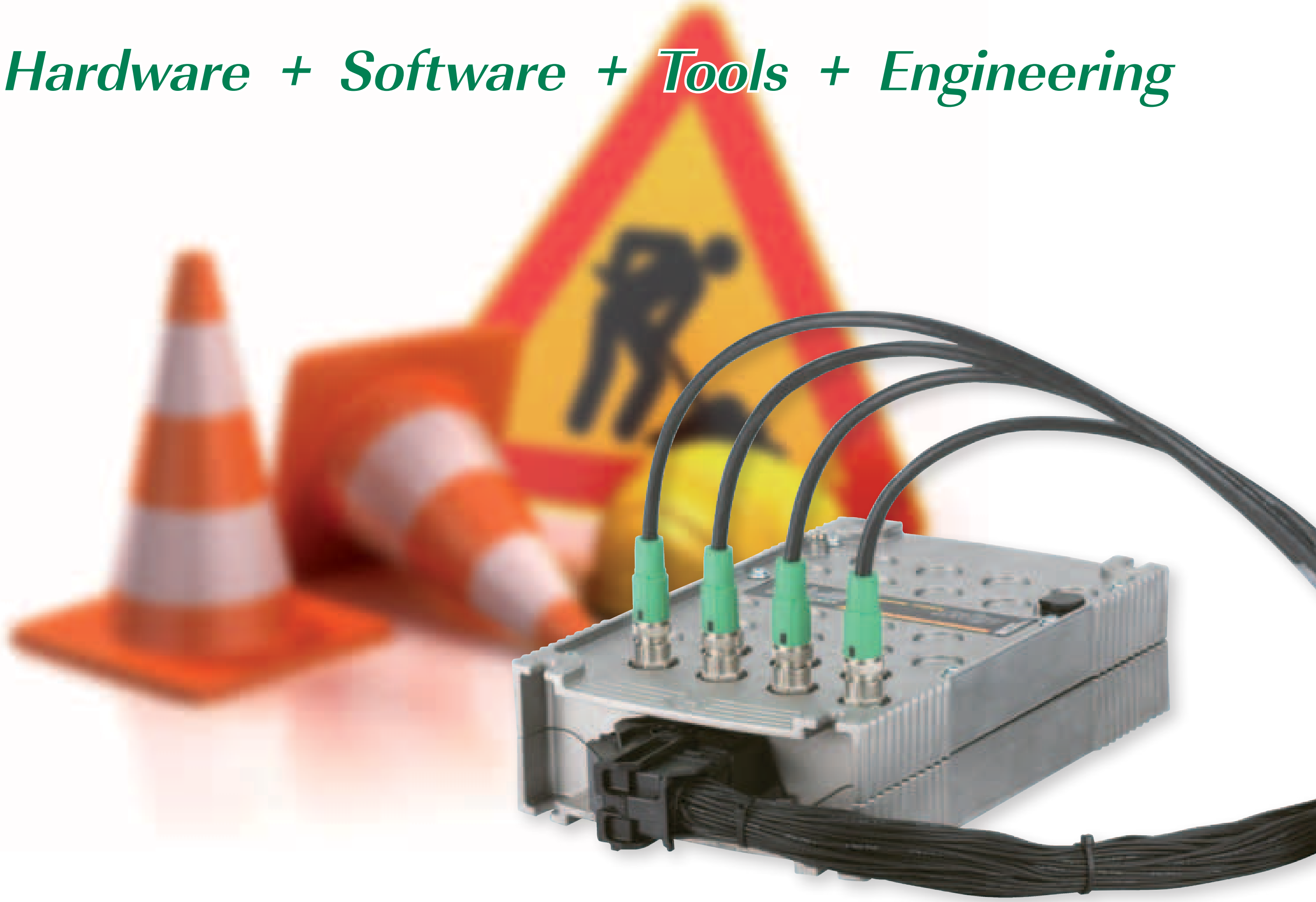

Safety first – The need for interoperability tests

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Safety first – The need for interoperability tests

Figure 1: Gallery of recently introduced safety PLCs suitable for mobile machinery providing CANopen Safety connectivity (from left to right: R360 by ifm, ESX-3XL by STW, and Digsy Fusion G by Intercontrol)

Abstract

At the Bauma 2013 in Munich (Germany), the world-leading tradeshow for construction and mining machines several suppliers introduced safety-related controllers and other devices compliant to the relevant safety regulations and related standards. Some of them already passed the test procedure by authorities and received a certificate – often by one of the German TÜV organizations. However, such a certificate doesn't guarantee interoperability by means of the network interface. This is not proofed by the authority organizations.

Boys' eyes widened when they were on the Bauma fairground, in particular in the open-air area. Excavators, graders, and other earth-moving machinery were demonstrated. Some of them were dancing and others were part of shows with dancing girls and boys. The heavy-duty machines made of iron and steel fascinated the visitors, not just the boys. What they don't knew was that these machines-on-wheels or caterpillars were controlled by sophisticated electronics.

Most of the electronic control units, sensors, actuators, and human machine interfaces in construction and mining machines are networked by means of CAN-based bus systems. The electronics need to be robust, reliable and since some years they shall provide increasingly functional safety. This is regulated in the European Machinery Directive 2006/42/EC, which has come into effect in end of 2009. This document references several not entirely harmonized international standards. Safety-related control systems can be assessed based on functional safety standards like EN ISO 13849-1 and IEC 62061, to fully meet the functional safety requirements resulting from the above-mentioned European directive relating to assembly and trade of machinery within the European Union. The EN ISO 13849-1 standard applies to safety aspects of controls and to all types of machinery, using mechanical, hydraulic, pneumatic and electrical technologies. The Performance Level (PL a to d) measures the safety performance. The IEC 62061 standard applies to the use of electrical, electronic and programmable electronic (E/E/PE) control systems for machine safety, and analyses the entire product life cycle. The Safety Integrity Level (SIL 1 to 4) assesses the safety performance. There is some standardization activity to merge IEC 62061 and ISO 13849, which should result in the new ISO 17305 standard. But any change in any safety standard means re-certification. A re-certification is also necessary, when one safety-related component is changed. This might happen quite often with micro-controllers. Of course, the re-certification is not that challenging as the first-time certification. On the other hand, it costs some money and delays business (read also the editorial "There are some unsolved problems!").

A firework of safety products

The last years, some electronic suppliers have developed products featuring functional safety. The first company offering a CANopen Safety compliant PLC was ifm (Germany). For a bridge inspection system (see CAN Newsletter 2006, June issue), two IEC 61131-3 programmable controllers exchanged SRDOs (safety-related data objects)

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Related articles
R. Wagner, I. Hornberger: CANopen Safety with Codesys Safety for SIL 2. CAN Newsletter, March 2013.
H. Zeltwanger: CANopen Safety – The forgotten protocol extension. CAN Newsletter, March 2010.

Product related information

More information about CANopen Safety products and other safety devices are provided in the CAN Newsletter Online magazine. This online magazine features a search function, so that users can find easily even older product information. It is also hyperlinked to the CiA product guides as well as to the suppliers' websites.

as specified in EN 50325-5 (formerly CiA 304). However, these PLCs don't provide an object dictionary, and therefore they are not CANopen device. Nevertheless, they can communicate with other CANopen Safety devices and manage them. Hirschmann MCS (Germany) was another early bird implementing the CANopen Safety protocol: The overload protection system for cranes and other construction machinery was based on the protocol already developed before the millennium by CiA members. Other controller vendors developed their own solutions for a SIL-2 compliant CAN communication. STW's (Germany) ESX family of host controller has been approved for safety-related applications. Some machine builders connected via CAN/CANopen two sensors measuring the same value to the safety controller in order to achieve a SIL-2 compliant communication. Sometimes, this was done because of the non-availability of CANopen Safety sensors. In the meantime, several sensor vendors have implemented CANopen Safety into their products. Pepperl + Fuchs, Posital, and TWK (all headquartered in Germany) provide encoders or/and inclinometers with CANopen Safety interfaces. CiA is updating the CiA 406 (encoder) and CiA 410 (inclinometer) profiles accordingly. They will be released soon. Other manufacturers have also introduced several CANopen sensors supporting CANopen Safety, e.g. FSG and Hirschmann (both are headquartered in Germany).

On Bauma 2013, Intercontrol (Germany) has launched its Digsy Fusion G controller. The safety device is programmable in IEC 61131-1 languages using Codesys 3.5 by 3S. The safety functions of the product comply with IEC 61508 and IEC 62061 as well as ISO 13849-1. The SIL-2 certified product features also CANopen Safety communication functions. The modular controller is equipped with two 32-bit micro-controllers. The base module provides 48 I/O ports and can be extended by stackable add-on modules to up to 240 I/O lines. The four CAN interfaces are supported by the certified CANopen Safety protocol stack, which has been implemented by the company itself. Additionally, the CAN interfaces may use CANopen, J1939, or proprietary higher-layer protocols. By the way, 3S provides CANopen Safety connectivity for its Codesys Safety SIL-2 software (see CAN Newsletter 2013, March issue). This TÜV certified PLC runtime software is dedicated for mobile machines. It is to be expected that some PLC makers already using Codesys will extend their product portfolio with safety controllers featuring CANopen Safety connectivity. But it may take some time, before authorities have certified those products.


Figure 2: The first CANopen I/O devices featuring CANopen Safety has been launched by TTcontrol

One of the unique features of Intercontrol's safety controller is the possibility to run safety and normal application software in parallel without any interference. This means, you can even after safety approval extend or change the normal application program. The safety controller with a Performance Level of d is suitable for category 2 and 3 applications according to ISO 13849-1. The devices' design is done in a way that most of the computing power can be used for application programs. STW's ESX-3XL host controller also available with Codesys Safety features a controlled separation fo safety-related and non-safety-related software functionality. The C application programming interface (API) meets the requirements for SIL-2/PL-d applications. STW claims to be the first ECU (electronic control unit) supplier that can fulfill the safety requirements for Codesys designs under IEC 61131-3 and IEC 61131-6. Another supplier of safety ECUs is TTcontrol (Austria), a joint venture by Hydac International and TTTech. This company is the only one, which also provides I/O modules with CANopen Safety interfaces. If you requireOf course, you can also use a CANopen Safety PLC running in NMT slave mode and use it as a programmable I/O module.

But if you can avoid programming safety software, this makes system design more easy. Therefore, Hirschmann has introduced on Bauma 2013 the Qscale I2 safe load indicator for small and medium-sized cranes, which is just configured and not programmed. Of course, it implements a PLC, which is not visible to

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30 years of experience in industrial computer systems

Janz Tec AG, has been one of the leading manufacturers of electronic assemblies and complete industrial computer systems since 1982. The company describes itself as *Industrial Computing Architects* and develops embedded PCs, industrial computers and industrial communication according to customer requirements.

Good communication is very important nowadays – not just in real life, but also in machines, plant and complex industrial applications from a wide range of industries. This applies especially if error-free transmission of data is required due to more and more compact construction and the necessity for more performance in the case of distributed systems. For this reason, Janz Tec AG also places great value on innovative and sophisticated technology in the industrial communication business sector. The InCom products developed in-house enable the control systems for your machines, plan and systems to be kept at the highest level.

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Figure 3: Besides several safety sensors, the industry supplies also SIL-2 compliant joysticks as the shown completely redundant devices by Bosch-Rexroth

the user. Codesys knowledge is not required. The related configuration tool is available in three versions (Service, Basic, and Expert) depending on what should be achieved: certain management functions, controlled calibration or complex crane diagnostics. The software includes the necessary functional tests for TÜV acceptance testing and necessary overload trips are provided to determine the parameters necessary to calibrate the crane.

The necessary safety sensors (also provided by Hirschmann) are optionally available with CANopen Safety interfaces. This includes the G-sens geometric measuring sensors, the F-sens force sensors, and the P-sens pressure sensors. Also MTS Sensor Technologie (Germany) has introduced CANopen Safety connectable sensors on the Bauma 2013. The Temposonics MH linear encoder can measure length up to 5 m. They are designed for hydraulic applications in mobile machinery. Bosch Rexroth presented in Munich its 4THEC5 SIL2 joystick, which is SIL-2 and PL-d certified. The device provide a CAN interface supporting CANopen or J1939 profile specifications. The internal product architecture features redundancy for all data flows. For each control element, two position sensors send separate signals to two micro-controllers, which check the consistency of the information using specially developed software.

Ifm has also launched a 32-bit PLC, which can process SRDOs as specified in EN 50325-5. It is already The SIL-2/PL-d TÜV-certified controller provides also normal (not safe) CANopen and J1939 interfaces. Safe J1939 communication is available from Sauer-Danfoss (Germany/Denmark). Of course, it is a proprietary not by SAE (Society of Automotive Engineers) standardized solution. The company has developed a generic safety protocol for CAN-based networks (see insert “Proprietary safety protocol”). It is applicable for CANopen, J1939, and Isobus (ISO 11783).

Interoperability testing

The authorities just prove that the functional safety functions are implemented correctly and according to the European regulations. They don’t care, if the device-under-test conformance to any communication protocol. Also interoperability between devices is something what doesn’t matter those authorities. Of course, the system designer is interested in all of them: Conformity to functional safety standards, conformity to the CANopen Safety protocol as well as the interoperability of con-

There are some unsolved problems!

The European Machine Directive 2006/42/EC is effective since 2009. Programmable devices controlling machines have to be compliant with it. Authorities such as the German TÜVs certify those products and machines. In general, the electronic devices have to follow the referenced international standards. When one of them changes, the products need to be re-certified. Of course: Because your design has to be state-of-the-art. And state-of-the-art is what is internationally standardized. No contractions. Unfortunately, the revision process of the referenced standards is not synchronized. This means, the manufacturers have to re-certify their products more frequently as they expected on the first glance. More worse: You need also to re-certify your safety product, when for example the micro-controller is changed. If you choose another micro-controller from another chipmaker, this is fair enough. However, if the very same chipmaker just introduces a follow-up micro-controller, which is function and software compatible, you also have to re-certify it. And this may happen more than once in the lifetime of the safety product.

Just a worst-case scenario example: You design a safety sensor. Let’s assume you are fast. After one and an half year, you have the safety certificate for your product. Unfortunately, one of the referenced standards (e. g. IEC 61508) has been released in a new version, in the meantime. You can’t sell the sensor anymore to machine builders, because it is not more state-of-the-art. Sorry, but a re-certification is necessary. You have to wait another half year before you can start selling the sensor. After this time, your chipmaker informs you that the micro-controller will be discontinued. Fortunately, the next version is pin and software compatible. Nevertheless, this requires a re-certification. You have to wait another few months, before you can make business. But you can’t, because another referenced standard is under review and will be published soon in the next edition.

You think, I am kidding. No, this is bitter reality. I think it is time to find solutions for such scenarios. Technically you can solve the problem partly by means of using FPGAs or other manufacturer-specific hardware solutions, which is never updated. But this doesn’t work for very small quantities, because it is too expensive. And the changing of standards is not solved at all. We need more safety for our investments, without reducing the safety aspects, of course. *Holger Zeltwanger* trollers and sensors or actuators featuring an open safety communication standard. This is why CiA will organize plug-fests for CANopen Safety devices. It is intended to proof those devices implementing the CANopen Safety protocol and the related profiles (e.g. CiA 406 or CiA 410) understand each other. It should be avoided that interoperability problems are detected during system design. The testing will be done during plug-fests. In such plug-fests, ECUs and PLCs will be connected to the sensors and actuators. The performed tests will include SRDO operational tests as well as the configuration of SRDOs.

Holger Zeltwanger

Proprietary safety protocol

Sauer-Danfoss has developed the Plus+1 CAN Safety Message protocol. TÜV Süd (Germany) has approved it. This protocol is independent of the used application layer. In difference to a non-safe CAN message, it is necessary to send an additional CAN data frame. This message contains a 3-bit sequence number, a 16-bit CRC protecting the safety data in the PDO (CANopen) or PGN (J1939 or Isobus), and the CAN-ID of the related CAN message containing the safe data. There is also a maximum time between the two related messages (called Safety Data Group), which shall not expire (Safety-relevant Cycle Time). The Safety Data Message (SDM) is sent first followed by the Safety Header Message (SHM). The SDM may contain safety data as well as non-safe data. The SDGs are sent periodically with the Safeguard Cycle Time (SCT). The Plus+1 CAN Safety Message protocol uses the sequence number and the additional CRC polynomial to detect single failures. The probabilistic analysis proofed that this protocol exceeds the requirements for SIL-2 and PL-d. The analysis was based on un-shielded wires, 255 receivers, and an 1-ms periodic transmission of SDGs.

Based on this concept, Sauer-Danfoss supplies devices using CANopen or J1939 connectivity. This includes ECUs for different purposes as well as hydraulic devices and joysticks.

The Fan Drive Control (FDC) by Sauer-Danfoss supports the Plus+1 safety protocol and is suitable for the company's H1 family of piston pumps

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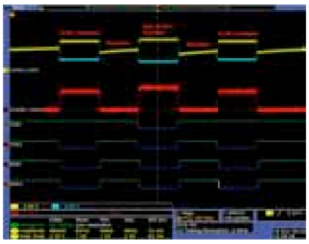

Engineering

First international Mobile Machine Control (MMC) conference

CAN in Automation (CiA) organizes the 1st international Mobile Machine Control (MMC) conference in Nuremberg (Germany). The 2-day event will take place in June 2013 (12th and 13th). The conference will focus on CAN-related topics, but also addresses other communication systems such as Ethernet and WLAN. The MMC program committee has selected 22 papers. Three sessions are related to safety control and communication. The other sessions include agriculture machinery, system and device design as well as application examples and tools.
Hirschmann MCS, Inter Control, Softing, Sontheim, and STW sponsor the conference. The event is accompanied by a tabletop exhibition. “This is the only international conference focused on the design of electronic control systems for mobile machinery including agriculture, construction, forestry, and mining machines as well as off-highway vehicles,” said Holger Zeltwanger, CiA Managing Director. “The selected papers range from application experiences to next generation control systems.” The main focus is on safety controller and safe communication via CAN and Ethernet networks.

More information about CAN-connectable devices featuring functional safety is available on CAN Newsletter Online (www.can-newsletter.org).

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Company milestones
1988: *Foundation of Vector Software GmbH on April 1st by Eberhard Hinderer, Martin Litschel, and Dr. Helmut Schelling*
1992: *Renaming to Vector Informatik GmbH and delivery of the first CANalyzer license*
1996: *Delivery of the first licenses for CANoe and CANape*
1997: *Foundation of Vector CANtech (USA)*
1998: *Foundation of Vector Japan*
2001: *Dr. Thomas Beck joined the companyVector as shareholder and 4th managing director tement*
2001: *Foundation of Vector Consulting GmbH*
2006: *Vector acquired 4m Software Division of Micron Electronic Devices AG*
2007: *Foundation of Vector Korea*
2009: *Foundation of Vector Great Britain, Vector India, and Vector China*
2010: *Aquintos became part of the Vector Group*
2011: *The ownership of the Vector Group was transferred to the non-profit Vector Stiftung and the Vector Familienstiftung*
2012: Thomas Riegraf joined the company management

“…and we, as engineers, developed products for engineers,” explained Martin Litschel, one of the three founders, the success of Vector. He believes that a company not located close to Daimler and Bosch would not have been able to have the same success. “It was a home game,” added Eberhard Hinderer, also a founder of the company. But the success has many fathers: “The CiA membership gave us the chance to present our first CANalyzer tool already in 1992 at the Interkama exhibition for chicken feed,” said Dr. Helmut Schelling, the third founder, remembering the early days of the CAN business. CAN network analyzing tools were also offered in those days by i+ME and Softing. “But, we discussed with our customers from engineer to engineer”, explained Litschel. “We were driven by our education background.” The result was a graphical user interface, easy to understood by engineers. “I had been involved in programming until 1998,” added Schelling, explaining the commitment and responsibility of the management in developing tools for engineers.

No doubt, today Vector is the market-leading manufacturer of CAN network analyzer tools. In total, the company has sold far more than 200,000 of their CANalyzers. They are used in development, production, and maintenance departments all over the world.

Figure 1: Vector has invested in bricks; the next buildings are already planned

From a 3- to an 1100-employees company

Vector, established April 1st, 1988, celebrates this year its 25th anniversary. Originally founded as an engineering office, the company is now a heavyweight in the CAN tool business and supplies also embedded software for the automotive industry. Nowadays, the company has subsidiaries in USA, Japan, France, Sweden, Korea, Great Britain, India, and China.

In the very early days, the owners did not want to take the responsibility to hire staff. But a couple of weeks later, they did it. “We have never planned the growth or the next steps,” said Schelling. “However, whenever there was need, we took the necessary decisions.” In 1994, the 25th employee joined the Swabian company. In 1999, 100 employees were already working in the Vector Group increasing to more than 500 in the year of 2005. Six years later, the number of employees exceeded the mark of 1000. Today the company employs some 1100 persons. The company has been awarded as an excellent employer. The European "Great Place to Work" initiative, together with the Handelsblatt (German) newspaper as sponsor awarded a quality seal for workplace culture to the 100 best employers in Germany. In 2011, Vector attained the 10th place in the category of companies with 501 to 2000 employees. The next award is in the pipeline: In 2013, Vector has been awarded the 2nd best employer in the IT industry in that category. The company also expects a good industry independent positioning.

While many rising stars in the young IT industry carried their gains to the stock markets, the Vector management invested in bricks, as Martin Litschel expressed it. The first company-owned building was finished in 2001, followed by a second in 2004. But this is not the end. “We are already planning the next construction stage with four additional buildings,” explained Hinderer, responsible for the project.

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Dr. Thomas Beck
President

Eberhard Hinderer
President

Martin Litschel
Founder and president

Thomas Riegraf
Founder and president

Dr. Helmut Schelling
Founder and president

Not just a "toolmaker"

By the way, the company's name derived from the first business: Programming NC machines using vector graphics. Starting with the making of bus analyzing tools in 1992, the company changed the name from the Vector Software origin to Vector Informatik. Nowadays, the company still makes half of the turnover with testing and tools. Of course, this includes the CANalyzer for testing ECUs (electronic control units) and the other well-known tools such as the CANoe for testing and simulation. The company supports all network technologies used in the automotive industry. However, the main business is still related to the CAN technology. So it is not a surprise that Vector is an early bird in the CAN FD development. The company already adapted the improved CAN protocol in analyzing tools, which were demonstrated several times on CAN FD events organized by Bosch and CiA. "CAN FD is the logical consequence, when you need more bandwidth," said Martin Litschel, one of the "inventors" of the CAN protocol. To the question, if the improved CAN data link layer is a competitor of FlexRay, he answered: "CAN FD is a competitor of FlexRay, only in those applications, in which time-triggered communication systems have no business."

The other half of Vector's business is coming from embedded software including operating systems as well as ECU calibration and application software development. Beginning of this year, the Microsar Safecontext operating system (OS) has been certified to ASIL-D in compliance with the ISO 26262 standard. The software certified by TÜV Nord (Germany) runs on the TMS570 processor by Texas Instruments. The concept is currently being extended to other processors.

Mixed ASIL systems require safe partitioning of software modules ("Freedom from Interference"). The certified OS supports this by protecting against overwriting of memory areas and by safe switching of contexts. The needed switching of the memory protection unit (MPU) and the switching of task and interrupt contexts was developed according to ASIL-D.

In order to cover also the hardware-near software development, Vector cooperates with iSystem (Germany) since this year. The companies have integrated their tools. The AMD and XCP options extend the CANoe development environment by adding the ability to access internal ECU values and to execute test and analysis tasks. In contrast to mere black box testing that only stimulates and measures external ECU signals, the ASAM standardized XCP protocol also facilitates the modification and analysis of internal ECU values. The main advantage is the monitoring of internal ECU parameters that cannot be measured over conventional bus communication. By modifying these parameters, it is moreover possible to introduce intentional fault conditions and directly test the resulting behavior of an ECU.

So far, memory access has been realized over CAN interfaces or ad- ▷

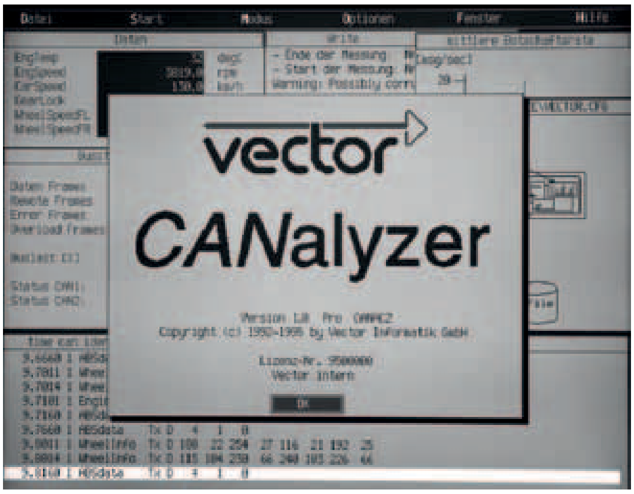


Figure 2: The first CANalyzer introduced in 1992

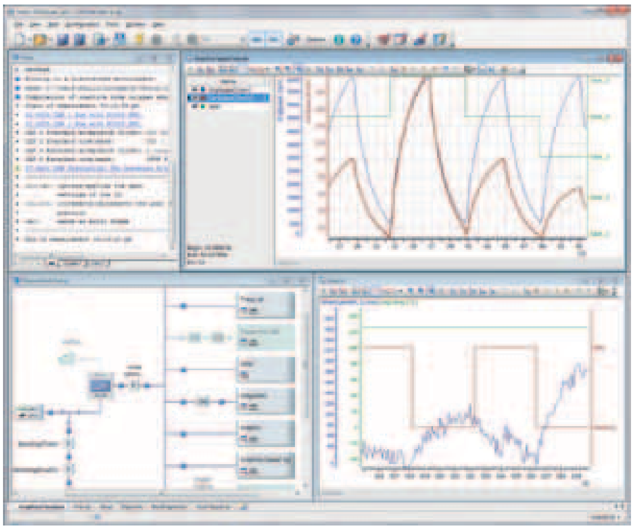


Figure 3: The current CANalyzer optionally supports different standardized higher-layer protocols including CANopen and J1939-based profiles

ditional VX1000 hardware by Vector. However, access had to be implemented in the ECU software. Regular communication limited the bandwidth of CAN-based XCP communication substantially. For specific micro-controllers, the VX product family offers maximum data rates of up to 30 Mbit/s, sampling cycles of 15 µs, and it can moreover be used in vehicles without any problems. The ECU code requires suitable conditioning as well.

With their joint development, both companies have extended the Vector's tools with the access technology of the iSystems's debuggers. This integration is especially helpful in the development phase, in which the debug interfaces can still be accessed externally.

For the time being, the debuggers support more than 3000 different micro-controllers that can be connected directly under CANoe.AMD, CANoe.XCP or CANape.

This access path to the ECU does not require any additional software or XCP drivers. No additional resources are used, and the real-time behavior is not affected.

Succession arranged

We all become older, and some day, we will retire. In order to avoid that financial sharks take over the company, the four shareholders of Vector decided to transfer ownership to two foundations. In August 2011, the regional administrative authority of Stuttgart (Germany) admitted the two foundations. The non-profit foundation, known as the 'Vector Stiftung', was endowed by the company founders Eberhard Hinderer, Martin Litschel and Dr. Helmut Schelling. It will receive 60 % of the company's shares. The family foundation (Vector Familienstiftung), which was endowed by Dr. Thomas Beck as well, retains the remaining 40 %, but consolidates 94 % of voting rights.

"Taking this step ensures a solid, long lasting basis upon which Vector can continue to develop and grow. This guarantees long-term continuity to our employees, as well as our customers and partners," said Dr. Thomas Beck. "Along with continuity, the foundation concept also guarantees that company profits will be reinvested in a meaningful and socially balanced way," adds Dr. Helmut Schelling. The goals of the Vector non-profit foundation are to support research for environmental-friendly mobility concepts, promote the development of young academics and support social institutions.

Eberhard Hinderer, Martin Litschel, and Dr. Helmut Schelling, already

Vector's view of technology trends in 2013

Vector Consulting Services published a study on future trends available on the companies website (www.vector.com/trends-en).

According to this study, 2013 calls for more efficiency and competitiveness, because the business climate is more fragile than before. The study derived from a Vector's customer questionnaire. The result: Companies will continue to invest in growth through innovation by developing new products and solutions, because this determines their market position. At the same time they are aware of the volatile market situation and thus trim their development teams worldwide to be as lean and as efficient as possible.

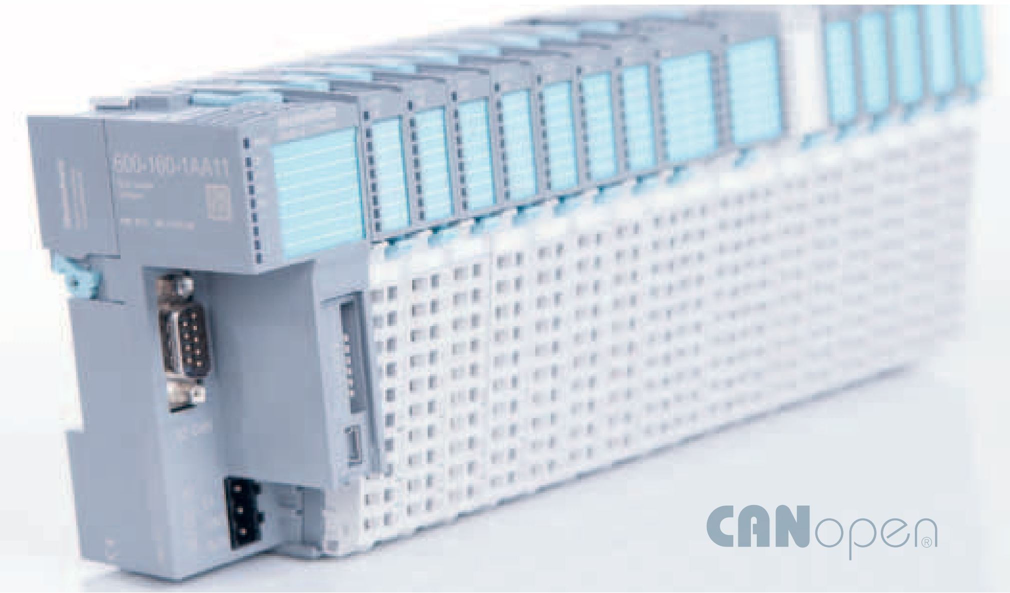
The year 2012 was very successful for most companies. In some places, however, change and investments had been avoided, since business "went very well" and teams had more than enough to do. That was a mistake, because product portfolios should be adjusted counter-cyclic. Now perceived cost restrictions are stronger. Automotive suppliers reported price pressure of three to twelve percent for the same products over one year. Others are so well established in their market that they can charge and get more than their competitors.

Vector Consulting Services has identified four trends:

- *Work with distributed teams*
  Set clear objectives for improvement and measure the agreed targets. Ensure a high level of discipline in distributed teams by transparently controlling both projects and results. Use tailored methods and tools for matching your own constraints and needs. Improve competences for distributed development and soft skills. For instance, using different communication channels rather than sending only mails.
- *Streamline the development*
  Streamline workflows and related tools stepwise, with an overarching strategy, incremental goals, and a future-oriented IT architecture. Set concrete provement targets on a quarterly basis. Train employees in "lean development". Give each team the task of developing their own action plan for reducing waste, rework and interface conflicts – with reference to your company-wide efficiency targets. Evaluate your performance, for example by sales per developer, lead-time, fault-detection rates and cost drivers. Make sure that agile techniques do not lead to arbitrariness. Apply professional change management.
- *Develop function-oriented and architecture-based*
  First establish a strong focus on systems engineering and modeling of functions and architecture. Support the interfaces to the different components through traceability, consistency checking and development automation. Prepare model-based development: Stepwise introduction, focus on critical components, continuity of requirements to code and test cases, and adjustment of your own processes. Do not primarily look on tools, but rather on integrated processes and a systematic methodology. Use environments to consistently model the different levels of abstraction, from functions to logic, from architecture to implementation.
- *Implement functional safety*
  Define safety requirements and measures early and consistently from a system point of view. Break it down only to components and functions, after the architecture impacts have been analyzed. Integrate suppliers and customers into your overall concept of functional safety. Reduce the cost of functional safety through integrated modeling, early defect detection and reuse. Optimize in parallel your engineering processes towards more efficiency. Do not copy the methods from the standards, but rather use the wide experiences of Vector for efficiently implementing functional safety.

close to the age of 60 years, plan to reduce gradually responsibility in the next years. “We don’t plan to retire now,” stated all three. In order to hand-over the company management as smooth as possible, mid of last year, Thomas Riegraf has joined the corporate management. Already in 2001, Dr. Thomas Beck joined the management. Riegraf has been working for Vector for 23 years. He was involved in the development of the CANoe and CANalyzer tools. “I look forward to assuming my new role and responsibilities at Vector. I will dedicate myself to these tasks with full commitment to advance Vector’s development in relation to our customers and employees,” said Thomas Riegraf.

Beginning of this year, Vector has reorganized its business with standardized higher-layer protocols. The department dealing with CANopen, Devicenet, J1939, Isobus and all the other standardized CAN solutions are integrated in the existing departments such as tools and testing, embedded software, and calibration. The protocol stack development has moved to the tool department. The avionics business unit is remaining as a strategic department, which is also responsible for the CAN-based avionics solutions (Arinc 825/6). “You should not misinterpret this reorganization,” said Dr. Beck. “We are strongly committed to standardization.” The company is present in many standardization committees and member of all relevant associations including CiA. “We even want to extend our business in the direction of commercial vehicles and other industries,” stated Thomas Riegraf. “But we don’t want to invest heavily in businesses, in which the prices do not match our company’s goals,” added Martin Litschel. ◄



“Our major business is high-quality CAN hardware”

Source: Ixxat Automation/Fotolia

Ixxat Automation is known for a long time in the CAN business. Official established at April, 1st in 1998, the company celebrated recently its 15th anniversary. However, when considering the predecessor – the STZP transfer center – the company looks back to a 25-years history. The CAN pioneering company is located in Weingarten close to the Lake of Constance in the South of Germany. The main business is still the development and production of CAN hardware products like interface boards and topology components. “Our major business is high-quality CAN hardware” said Christian Schlegel, CEO of Ixxat. “We produce per year about 50000 hardware components, which makes more than two thirds of our income. About 80 % are CAN-connectable units.” This includes PC interface products, gateways, infrastructure components like CAN repeaters and bridges as well as CAN hardware specifically designed for OEMs. The other turnover comes from software (15 percent), e.g. protocol stacks and engineering services (15 percent). A market analysis conducted internally last year showed that the company belongs to the market leaders or even is the market leader related to the worldwide supply of CAN interface boards and CAN infrastructure components.

Christian Schlegel was involved from the beginning in programming protocol stacks: “I started with a Profibus slave implementation, developed the first CAN Application Layer software, and continued programming our first CANopen protocol stack.” Today he manages the company, still participating in the technical meetings and discussions company-internally as well as with customers.

The question, what were the most interesting and challenging CAN applications, he has seen in his 23 years working for Ixxat and STZP, he answered: “The project for Kongsberg’s ship automation system with its redundancy and high-availability requirements, was the most challenging one.” The Norwegian company equips about 1000 vessels per year with this jointly developed system.

▷

Figure 1: The management (from left to right) – Christian Weißenrieder (Financial Director), Markus Demaria (R&D Director), Christian Schlegel (Managing Director), Thomas Waggershauser (Sales & Product Marketing Director)

Company history

- ***1998:*** *Foundation of Ixxat Automation and transfer of the STZP employees and business*
- ***2000:*** *Foundation of daughter company in the USA (New Hampshire)*
- ***2002:*** *Start with Flexray technology (execution of verification tests for the Flexray consortium)*
- ***2005:*** *First real-time Industrial Ethernet and IEEE 1588 projects*
- ***2006:*** *Entry into safety technology according IEC 61508*
- ***2008:*** *BWK becomes majority shareholder*
- ***2011:*** *Foundation of daughter company in France and sales offices in Switzerland and Italy*
- ***2013:*** *HMS Industrial Networks acquired Ixxat*

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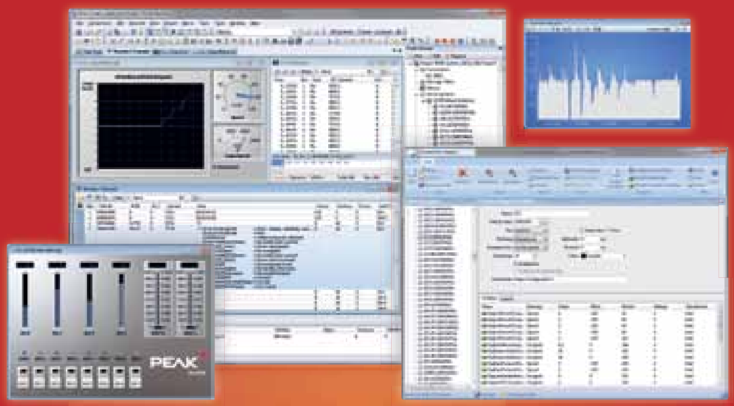

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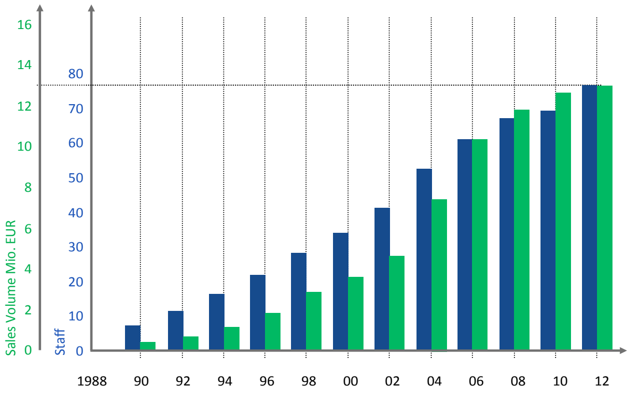


Figure 2: Annual sales volume and staff development

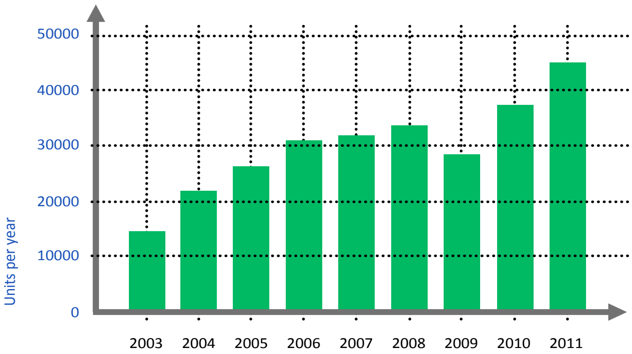


Figure 3: Annual sales figures of CAN interface products in units

One of the largest CAN designs was done for Otis: The lift (elevator) control system comprises in maximum about 18000 nodes. “We developed a specific CAN higher-layer protocol based on the 29-bit identifier, in order to address so many devices from any location in the hierarchical system,” explained Schlegel. He also mentioned two medical applications, which have impressed him: The integrated operating room by Karl Storz and the eye-surgery system by Alcon Labs. In both projects the CAN PC interfaces from Ixxat are used. The operating theaters by Karl Storz are based on the SBC network, a CAN network with a CAL-based proprietary profile. The SBC network was first used in the company’s equipment for endoscopy surgeries. In the meantime, the SBC is also used in the OR1 integrated operating room.

HMS acquired Ixxat

Ixxat, founded by Prof. Dr. Konrad Etschberger, was acquired beginning of this year by HMS, a Swedish company focused on communication interface prod-

Christian Schlegel (Ixxat)

23 years in the CAN business

I had the privilege of accompanying and helping to shape a large part of Ixxat’s history. So I’d like to take a look back on it, but also forwards into the future.

When Prof. Dr. Konrad Etschberger established the Steinbeis Transfer Center for Process Automation (STZP) in 1987, the first field buses like Profibus were just being introduced. When the first Intel CAN controller became available, STZP was asked by ZF to evaluate the component. Starting with the requirement of being able to connect PCs to a CAN network to make the data traffic visible, a CAN interface card with an ISA bus interface was developed, and became STZP’s first product.

Although CAN was designed for use in the automotive sector, STZP concentrated on the use of CAN in industrial applications. In 1990, STZP was the first provider of CAN seminars, and in 1992 it became a CiA member.

When I joined the field-bus topics as an engineer at the STZP in 1990, I worked intensively with the development of a higher-layer protocol (HLP) for CAN. The definition of a HLP for CAN was thus the first CiA specification. In 1994, the CAN Application Layer (CAL) was published. That ultimately became CANopen, whose first specification was released in 1995. STZP and later Ixxat were heavily involved in the development and further refinement of the CANopen specifications.

Over the years, STZP’s product portfolio was expanded, so by 1998 they offered a comprehensive product range of CAN-PC interface cards and CAN repeaters, as well as analyzing tools and protocol software packages for CAL, CANopen, and DeviceNet.

To demonstrate more professionalism, give employees a longer-term perspective, and also to leave the university fold, Ixxat Automation was founded in 1998 and STZP’s technology and employees were transferred to it.

In the years after 1998, more and more technologies were added, e.g. Ethernet/IP in 2001. Then, in 2002, we worked on the introduction of Flexray (after previously working on the Byteflight protocol with BMW). In 2005, Powerlink followed, another Industrial Ethernet solution.

An important first step in the global market was the founding of US daughter company in 2000. In 2011 and 2012, we've added our own sales offices in Italy and Switzerland, along with another subsidiary in France. We have a global sales network of 18 distributors not counting the HMS offices and distributors.

In the future, we will concentrate (besides the CAN business) on three additional topics: safety, Ethercat and Powerlink. We would like to extend our heartfelt gratitude for the last 25 years for the established customers who have accompanied us on our journey. It’s been fun. And we are looking forward to future that we can experience together, as well as to the new technologies and challenges that will come during that time. CAN FD is one of the next one we will invest in. We are already developing with a partner an FPGA solution supporting the improved CAN protocol.

ucts and gateways. The company’s shareholders (the BWK investment company, Prof. Etschberger, and Christian Schlegel) sold the firm completely. It is now a HMS daughter managed by Christian Schlegel. “I think the acquisition will give us the chance to improve our presence worldwide,” said Schlegel. “HMS has more than 80 people in its worldwide sales departments at the Swedish headquarters and 10 international subsidiaries as well as a much wider distribution network as we had in the past.” Both companies have already joined their sales forces by means of building sales teams. For Germany, Switzerlandn France and Austria one sales team was established, and this also already happened in USA and Italy. “We will be the competence center for CAN technology, safety, Ethercat, Powerlink, and will have an important role as customized hardware provider within the HMS group. Ixxat's ambition is to stregthen our position as a major supplier for customized CAN hardware and for all CAN related technologies." Basis for the hardware production are the HMS group factories in Germany, Sweden, Lithuania and China where the HMS group produces 400.000 hardware products per year at very high quality standards.” said Schlegel. HMS – not that successful with CANopen as with Profibus – also benefits from the well known CAN company and its customer base. “Their strong position especially on the German automation market will strengthen our presence in Central Europe,” said Staffan Dalström, HMS’ CEO. “Together with our subsidiary in Karlsruhe, Ixxat will reinforce HMS in Germany - the world’s leading market for industrial communication solutions.”

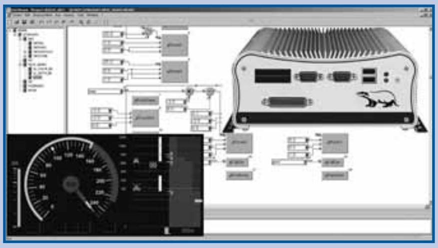
CAN FD products will come soon

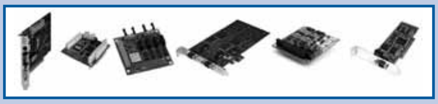
“We have not yet scheduled in detail, the support of CAN FD in our products,” said Schlegel. “But by end of this year, you will see the first CAN FD products from us.” The company will extend its CAN drivers (VCI – Virtual CAN Interface as well as ECI – Embedded Communication Interface) in order to support the higher payloads of up to 64 byte. However, the next version of the CANanalyser tool (version 3.0), which is to be released beginning of summer this year with some interesting add-on features (for more details visit the CAN Newsletter Online) will not yet support the improved CAN protocol. However, CAN interfaces and also the bus-analyzing tool with CAN FD support will be presented at the 14th iCC (international CAN Conference) in November in Paris. “I see a prospering future for CAN,” stated Schlegel. “CAN networks are cheap and easy to maintain compared to Ethernet-based solutions. And with CAN FD we have now a migration path to higher bitrates resulting in higher throughput.”

The company has been a very active CiA member participating in many CiA technical working groups. Besides in the CANopen Interest Group,

Ixxat employees were present in several Special Interest Groups such as dealing with contrast media injectors, gateways to wireless networks, layer setting services, etc. “We will continue to support CiA in its specification activities,” promised Schlegel. “We as a small company regard CiA as one important factor of our success. Together with HMS, also a CiA member and other CiA members, we will continue to develop jointly CAN technology for different markets.”

Holger Zeltwanger





Exception management in CANopen systems

Dr. Heikki Saha

Author

Dr. Heikki Saha

Introduction

The first section of this article describes briefly, how physical layer appearances can be indirectly monitored with the application layer services which are the main constraints. Next section presents, how status of any device can be presented without project configuration information. System membership and connection monitoring principles are presented in last two sections before discussion.

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Common misunderstanding in the industry is, that emergency (EMCY) protocol is the main exception management service in CANopen systems. On the contrary, there are exception management features as part of each communication service, and standardized design process and files provide a systematic approach to reduce design errors. Many services, dedicated for both exception management and troubleshooting, have been presented in the literature. They are briefly reviewed and readers are advised to read the referenced publications for more details.

Implementations with discrete I/O cabling have typically been managed with human readable electric drawings and separate, written parameterization instructions, which have caused deviations in quality. In addition to the communication services, CANopen includes also design processes and files to avoid design failures and configuration inconsistencies [2]. Systematic parameter management approach enables flexible use of off-the-shelf components throughout systems life cycle, so that standard process files, and tools can be used to hide the complexity in assembly and service [3].

Various exception management features are available during system operation. Properly configured NMT-master starting only valid devices with various optional checks is the first efficient safeguard, which can be configured as simple as allowed by the application. The design process provides error-free information for run-time parameter transfers [5]. Furthermore, metadata of the parameters can be utilized for e.g. checking plausibility of the parameter values and preventing parameter editor to exceed the defined value ranges.

Signal status monitoring and plausibility checking are based on the information provided by the design process and files [5]. Both NMT status of the producer and signal update interval can be used to confirm both correct producer state and update of each incoming signal at required interval. Signaling dependability of CAN communication with application layer safeguards is several magnitudes higher that can be achieved with discrete inputs and outputs [6].

Of course event list functionality based on EMCY protocol is supported. The usability of such concept can be significantly improved by expanding the capabilities of the design files [7]. Proposed additional features enable error code management as an integral part of the design process. It should be noticed that event list is intended to be used together with the other exception management services. Typically, event list is used to provide notifications and other services can be used for more detailed diagnostics, based on the source node-IDs indicated by the EMCY consumer.

Physical layer

It has been well known from the history of CAN that increasing the number of nodes in a network decreases residual error probability because each node is monitoring the communication and is able to globalize locally detected errors [1]. It is obvious that the more there are devices monitoring the communication, the bigger portion of all errors – part of which can be local to certain positions of the network – can be detected.

▷

```
SYS_PRS
     Sensor
     Trafag AG
     P/N: 2288415779
     R/N: 1.4
     S/N: 204250000
     Errors: GE
```

Figure 1: Example device monitor window with a generic error pending

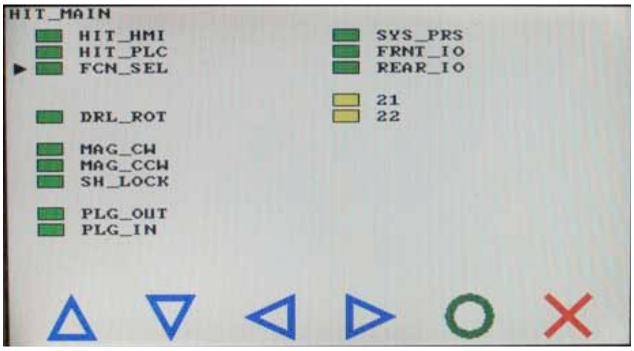

Figure 2: Example membership monitor window with two invalid devices found from the system

Majority of the physical layer errors are covered by CAN controllers and main CANopen communication services [5]. Some effects of undetected corruption can be detected by plausibility checking based on signal metadata exported from CANopen project to software project [5] [6]. CANopen is very reliable and the probability of undetected erroneous frames is extremely low [6]. Physical layer appearances have effects on application layer behavior, where indications can be processed and visualized for operators.

Combinations of signal timeouts and device states can be used for distinguishing physical layer failures from communication or configuration errors [5]. The main problem of termination resistors is that they are not active components. As a consequence, their condition can be determined quite well but not perfectly.

If adding devices introduces communication problems, physical layer specifications have been violated. Most obviously wrong protection circuits have been used in the devices, causing impedance mismatch in the transmission line. Other common reasons are topology violations causing reflections disturbing the communication. It is also possible that the maximum number of nodes supported by transceiver chips has been exceeded. It is assumed in further sections, that systems are designed and assembled correctly.

Device monitoring

Basic device monitoring can be implemented as a standard stand-alone software component, without any information from the system or components. Such characteristic is attractive, because it enables efficient approach to provide the basic device monitoring for all systems without project specific workload. Typically this kind of components can be used for troubleshooting e.g. from the beginning of the projects or with early prototypes.

Very basic implementation is included in the example in Figure 1, where only CANopen mandatory information is shown. This set of information is supported by each CANopen device. Device type is decoded based on lower word value, which indicates the supported device profile. Vendor-ID is decoded into vendor name based on the information maintained by CiA. Revision number is shown in the standardized format (major and minor). Product code and serial number are shown as raw decimal values. Error register flags for pending errors are decoded as abbreviations due to a constrained screen size.

The basic approach supporting only CANopen mandatory information can be expanded with CANopen optional information such as Manufacturer Status or Predefined Error Field objects. While the first one sounds interesting, its contents are free and are thus not possible to decode without device specific, detailed information. The benefit of showing the latter one may also be marginal, because the same information already exists on the event list. Thus, device profile specific information would be more attractive, because it can be decoded in details based on higher word of device type.

Drives support device control, status information as well as various information and status objects defined in device profiles. It means that if the objects are supported, they indicate same behavior and can be found from same object locations in each device [12] [15]. Encoders indicate support and activity information for both warnings and alarms, which enables extensive diagnostics without a need for system configuration or exact product information [14].

Measurement devices – e.g. pressure and temperature transmitters – provide signal type, unit and scaling information [13]. Comparable information is available from inclinometers too [16]. I/O devices support e.g. polarity selection for digital I/O and scaling for analog I/O, but generic structure of such devices makes it difficult to decode the status without detailed device information [11].

Membership monitoring

Basic membership monitoring in CANopen systems can be based on one the most fundamental CANopen service, heartbeat consumer. Fixed screen locations are used for each node-ID, which enables the use without project information in e.g. early prototypes. Membership monitoring can be improved by position names, which can be automatically collected from system's ▷

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[16] CANopen device profile for inclinometers, CiA 410, CiA

CANopen project. It is possible to display status of all devices – valid or invalid – in a system in this kind of view. There is no mapping into system structure, but the use of system specific position names improves understandability. Node-ID need to be used for possibly existing invalid nodes.

Source information can be taken from either local heartbeat consumer or from Request NMT object [9] of a remote network accessed with remote SDO service [9]. NMT states are read with a standard function block [5] [10] to an array for the further processing.

An example membership monitor is presented in Figure 2. In addition to the valid devices, there are two devices, with node-IDs 21 and 22, invalid to the example configuration. Valid devices have been started and green color indicates NMT operational state. Invalid devices have not been started and they remain in NMT Pre-operational state indicated by yellow color. If a boot message is sent by the device, but heartbeat is not available, the NMT state is unknown. If neither boot message nor heartbeat is available, the device is missing.

Connection monitoring

One of the main advantages of distributed control systems, when compared with the use of centralized architecture with discrete I/O, is an intrinsic support for connection state monitoring. Connection state monitoring can be based on information from heartbeat consumer of the devices combined with device installation order. Using GraphML based file format for system structure description and automatic code header generation from it is already proven technology [4]. As membership monitoring, also connection monitoring works as well for local as remote networks.

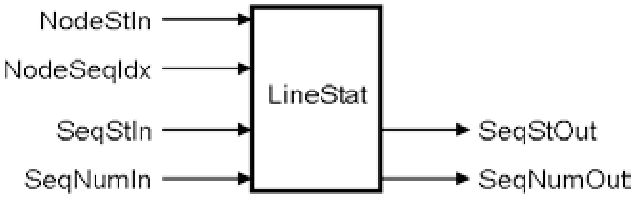

Figure 3: Basic analysis function block producing status of a single connection

Figure 3 presents the LineStat basic function block for monitoring a single connection. There are two inputs for the target node of the connection, NodeStIn for NMT-state and NodeSeqIdx indicating the node installation index from the beginning of the network. Two daisy-chained signals for error position and recovery indication are also used.

If a device exists and there is no error indication in SeqNumIn but status is not correct, the node-ID of the device is set into SeqNumOut. If an error indication exists in SeqNumIn, it is directly propagated into SeqNumOut. If a device with correct status exists after one or more failing positions, SeqStOut is set to true. True state in SeqStIn is always propagated into SeqStOut.

An example system is presented in Figure 4. It has linear topology and it consists of N nodes installed and R:th node is monitoring the system status. Array NmtSt holds NMT-states in the ascending node-ID order and array NIds holds the node-IDs in ascending installation order. System monitor does not natively support indication of invalid nodes, because their location is not known and cannot be determined unambiguously.

Error free status is fed from the monitoring position towards both ends of the network. If either SeqNumOut is greater than zero and both SeqStOut signals are negated, non-zero value points directly the faulty connection from the begin of the network. If either SeqStOut is asserted, there is most probably a termination failure. Proposed approach in most cases reveals both missing terminator and one installed in a wrong location away from either end of the network.

Another approach would be to indicate terminators potentially failing devices in all errors, which may be more confusing for the service personnel. In some cases one missing or wrong terminator does not cause immediate visible effect on communication. Furthermore, e.g. power supply failures may cause similar NMT state combinations.

An example of system monitor with combined membership and connection monitoring with 2D background is presented in figure 5. In more complex systems, so called 2.5D background could be used [4]. Various 3D visualization technologies can also be used, depending on the capabilities of selected display hardware. Termination error is suspected because there is one operating device after failing device. A cable break is also detected, because all devices from certain point to the end of the bus are failing. Color or potentially failing connection and terminators is set to red.

The use of intelligent sensors and actuators increases the number of nodes and improves the dependability and accuracy of system status information. It is obvious that increasing number of nodes will increase the accuracy of connection monitoring because there are more and shorter connections. As explained in the physical layer section, increasing the number nodes increases the dependability of the communication also in CAN level.

Summary

Following thoroughly defined design process and storing configuration information in the standard files will prevent majority of the design inconsistencies. During operation CANopen systems can indicate to operators most of the failures based on the most fundamental communication services, without any external measurement tools. Failures include configuration inconsistencies, broken network connections and problems in parameter and signal transfers.

Device and membership monitors do not require project information, but such information improves usability of the membership monitor. Operation of membership monitor without project

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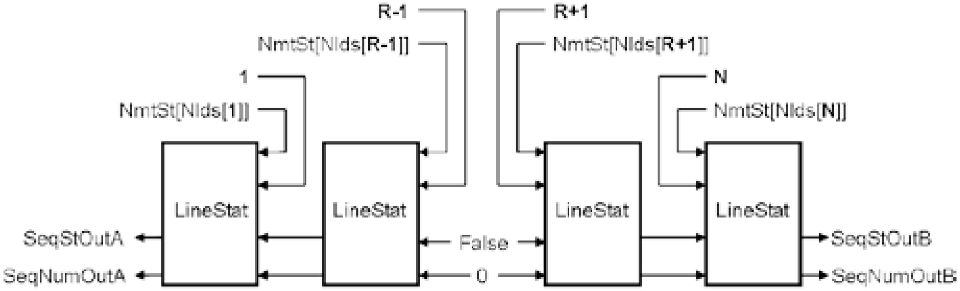


Figure 4: Analysis of a linear network using the basic function block

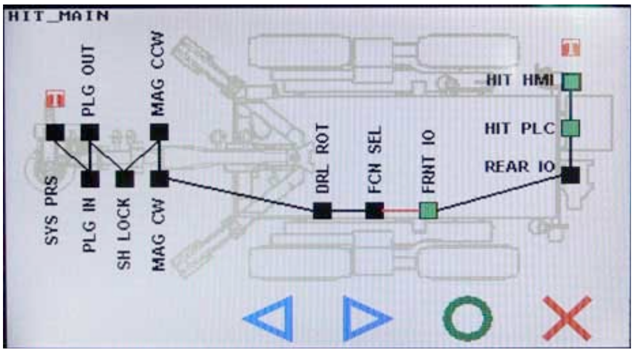


Figure 5: Example connection monitor with 2D background and active connection and termination failure indications

information enables indication of existing invalid devices, too. System monitor needs both structural information and device names of a system. Because of strong system dependence, existing invalid devices cannot be indicated in an acceptable way.

Connection monitoring was implemented as an example for linear topology. Other topologies can be covered later on, when standardized method for defining such topologies become standardized. Same basic analysis function block can be re-used, but instead of generation parameter header section, a whole top-level diagnostics function block would need to be generated from the network project. Such approach moves the most complex processing from the system to the design process.

Finding out termination failures remain challenging, because terminators are passive components and the overall behavior of networks depend on the physical layer characteristics such as topology deviations and specific impedance of the used bus cable. Therefore terminator failures are very difficult to be found, even with direct physical layer measurements. Proposed primary termination failure handling has been found practical in most cases, regardless of its incompleteness. Alternative approach will lead to more unnecessary terminator checks.

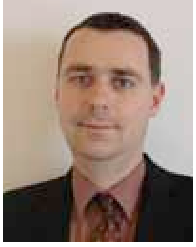
Against common understanding among engineers, increasing the number of nodes in a network increases troubleshooting accuracy and reliability in both CAN and CANopen levels. If increasing the number of devices disturbs the communication, there are serious physical layer design or installation failures in the network.

There is no sense in inplomenting manufacturer specific communication mechanisms because the existing fundamental features are supported by each CANopen device. Maximum compatibility enables the best possible maintainability of the systems, because devices can be selected based on application requirements, without any communication related constraints. Different visualization may be required by different applications and many features of the new system structure description format [4] support future visualization technologies. Main future research will focus on adding a support for more complex topologies to the connection monitor. ◀

Energybus: an open specification for LEVs

Torsten Gedenk

Author



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Introduction

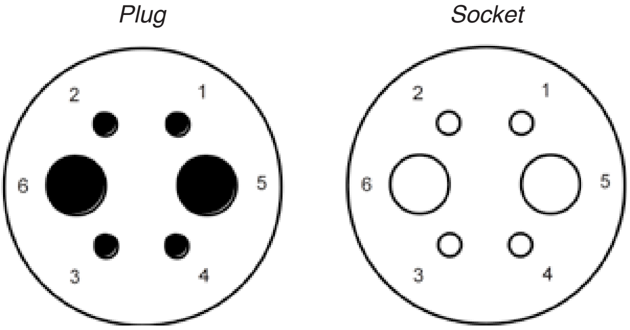
This article explains the motivation and development of the CiA 454 profile also known as Energybus network. The focus is on the defined communication protocol that was developed jointly by CiA and the EnergyBus members. The CiA 454 CANopen application profile specifies the parameters and communication services for light electric vehicles.

The electronic system of pedelecs (*ped*al *elec*tric *cycle*) and e-bikes comprises different devices, which use networks to communicate. It can be extended by additional devices for example to charge the battery. The light electric vehicle (LEV) market is currently characterized by numerous proprietary solutions for the communication between devices and chargers. Vendors of e-bikes cannot use devices from different manufacturers due to missing compatibility. On the contrary, many E-bike manufacturers and customers wish to have replaceable devices with different feature sets and the possibility to charge their e-bikes or pedelecs at public charging stations without the need to bring an own charger.

Figure 1: The Energybus connectors

To improve this situation, the Energybus association with currently 64 member companies is developing a standardized interface for these devices. This open specification for devices used in light electric vehicles (LEV) specifies the communication and connectors. The standardization offers advantages: Manufacturers require less adaption for different e-bikes, provider need less cables and adapters. Customers will be able to charge their e-bikes at public charging stations in the future.

First successful results have been reached both for national and international standardization. In the national cycle traffic plan the German government has committed to develop a non-proprietary LEV charging infrastructure by 2020 and the international standardization within ISO and IEC has been started in December 2012 in Shenzhen (China). First pilot projects with public Energybus charging stations are also running in southern Germany and Austria.



Pin	Signal	Description
1	CAN_H	CAN_H bus line
2	CAN_L	CAN_L bus line
3	AUX_V	+12V auxiliary voltage
4	AUX_GND	Auxiliary ground
5	POW_V	Power line voltage(bis +48V)
6	POW_GND	Power line ground

Figure 2: The table shows the pins of the pin assignment

CAN and CANopen

At the beginning of the development it was evaluated, which network protocol fits the requirements. CAN, LIN, USB, I²C and EIA-485 were taken into account. CAN has been chosen because of its robustness, flexibility and wide-spread use and availability. As CAN does not define an application layer protocol there was the need to define one. Instead of developing a new protocol from scratch,

Example: Battery

The CiA 454 specification defines all parameters for each virtual device. For batteries these are the following parameters:

All devices must provide the following parameters:

- Supported virtual device
- Device status
- Device capability
- Rated voltage
- Control word

A battery must additionally support all mandatory parameters for active devices:

- Maximum continuous input current
- Maximum continuous output current
- Maximum and minimum voltage
- Allowed peak value for input current
- Allowed peak value for output currents
- Actual voltage and current values
- Request of voltage or current limitation

And there are battery-specific parameters:

- Type of battery
- Actual capacity
- Rated capacity
- Temperature
- Cell voltages and currents
- Deep discharge counter
- Short-cut counter
- Over-temperature counter
- Total Wh output

it has been decided to use CANopen. Therefore, the Energybus association initiated the cooperation with CAN in Automation (CiA). The CANopen protocol provides a set of services to exchange data between devices (nodes) in a network. One of the most important services is the PDO service – Process Data Objects, which allow the transmission of process data in CAN messages without additional protocol overhead. The SDO service (Service Data Object) provides a random access to all defined device parameters. Additionally, the CANopen communication and application profiles define a set of parameters (object dictionary), which have to be available at all CANopen or profile-compliant devices. CANopen networks can consist of 127 devices, which can be addressed by its node-ID. The node-ID can be fixed (static or configurable) by DIP switch or dynamically assigned by the Layer Setting Service (LSS), which is similar to DHCP service. Device errors or alarms are signaled in CANopen by emergency messages.

CANopen application profile

In contrast to CANopen device profiles, the application profiles define a complete application, in which devices can be changed without reconfiguration. Application profiles define a fixed set of device properties and behavior and reduce the flexibility of CANopen to the needs of the application.

The LEV communication is defined in the CiA 454 application profile. It defines a set of virtual devices with defined properties and configuration parameters. One or more virtual devices can be combined in each physical device. Currently the following virtual devices are specified:

- Battery
- Voltage converter (Charger)
- Motor control unit (MCU)

▷

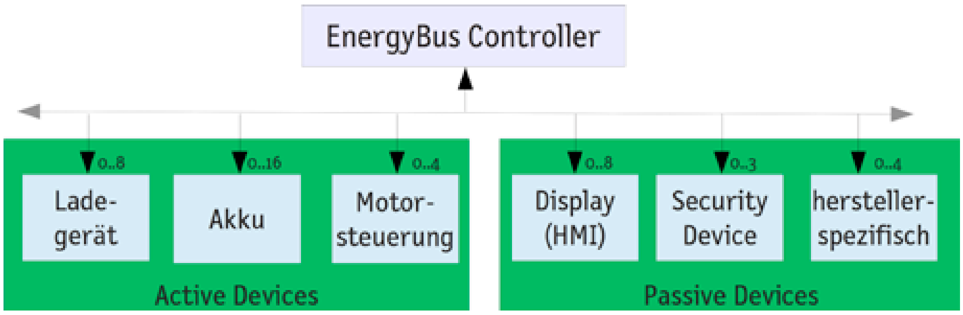


Figure 3: The LEV electronic control system comprises active and passive devices

- Display (HMI)
- Energybus controller as network master
- Security device

Additionally the CiA 454 profile defines the parameters in the object dictionary, the state machine for each virtual device, the process data which are sent by means of PDO with their cycle-times and further properties. The profile covers further definitions for Emergency messages and defines the use of dynamic node-ID assignment by LSS and the maximum number of virtual devices. CiA 454 devices are distinguished in active and passive devices. Active devices like the batteries, the chargers and the motor controller are connected to the power line (up to 48 V). The passive devices are powered by 12 V. The profile additionally defines a bit rate of 250 kbit/s. The physical layer shall be compliant with ISO 11898-5 (high-speed transceiver with low-power capability).

The CiA 454 version 1.0 covered only chargers and batteries; it was released in March 2011. In the next version, other parameters and the behavior of additional virtual devices will be specified. It will be released in 2013.

Energybus controller

The Energybus controller (EBC) provides the application master and the NMT master functionality. In addition, it assigns the node-IDs by means of LSS and the configuration of the devices by means of SDO. It also performs a compatibility check for each device. The power lines are only enabled if all devices signal that they are able to handle the provided voltage. Another task of the EBC is monitoring of all devices and reactions on device errors or loss of devices.

The EBC virtual device can also be implemented together with other virtual devices in one physical device. For pedelecs the EBC will mostly be combined with the motor controller. Another use case is the implementation of EBC in a charger. In this case, the EBC is allowed to be active, if it is the only EBC in the network.

From the CANopen point of view the EBC has to implement the following functionalities: NMT master, dynamic object dictionary, LSS master with Fastscan functionaltiy, SDO client, Emergency consumer, Heartbeat consumer, PDO producer and consumer as well as SYNC producer with 100-ms cycle time.

The state machine shown in Figure 2 ensures that the battery is only attached to the power line if requested by the EBC. One of the advantages of the CiA 454 profile specification is that all Energybus-compliant batteries (and other active devices) provide the same parameters and can be configured in the same way. Although, public charging stations will be able to charge batteries from different manufacturers and Energybus tools will be able to communicate with all CiA 454 devices. Furthermore there can be more than one battery in one Energybus network, in order to increase the achievable distance of the LEV.

In order to implement the CiA 454 profile, we provide the Energybus framework, which encapsulates all CiA 454 services and state machines. Using this framework detailed knowledge of Energybus and CANopen is not required for developers of Energybus devices. ◀

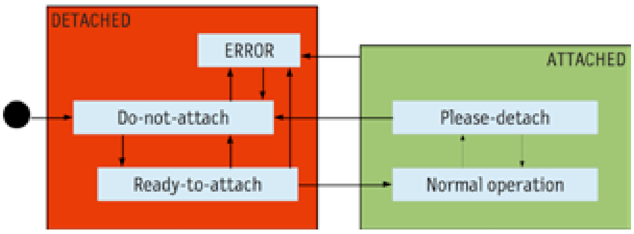


Figure 4: The firmware for the battery is mostly integrated in the battery management system and implements the shown state machine

Pedelec markets

In China, there are sold more than 20 million of pedelecs per year. In Europe, the annual sales figure is just one million. In 2011, this resulted in a sales volume of about 1,7 billion €. It has been predicted that in 2015, 3 million light electric vehicles (LEV) will be sold in Europe, and these will mostly be pedelecs.

Energybus connector

- Voltage up to 48 V (power line)
- Current up to 50 A
- Two pins for power (Powerline)
- Two pins for 12 V auxiliary voltage (for passive devices and to wake up deeply-discharged batteries)
- Two pins for CAN communication
- 5000 matching cycles
- magnetic reverse polarity protection
- Pulling out without damage is possible

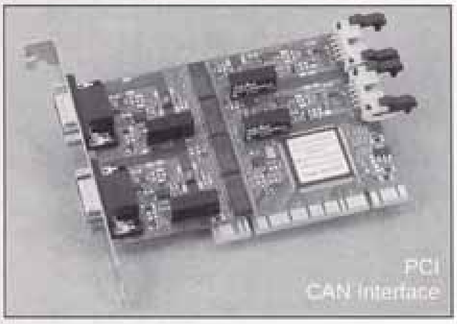
Reference

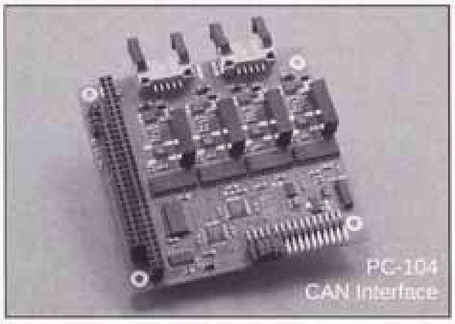
Jakob Wachtel, One CANopen Application Profile for Mobile and Stationary Energy Management Systems, Proceedings of the 13th international CAN Conference, 5 March 2012


PCIe
CAN Interface


USB
CAN Interface


NEW PRODUCT
PCI-104
CAN Interface


PCI
CAN Interface


PC-104
CAN Interface


Ethernet
CAN Interface

Evaluating performance levels of machine control functions

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Introduction

This article brings out some challenges in the process of defining the PL of a safety function implementation. One of these examines the use of different cabling schemes of the SRP/CS and their effect on the PL evaluation. The challenges are highlighted using a generic example of a safety function relating to a mobile work machine where different technologies (electrical, hydraulic and pneumatic) can be utilized. The different principles and solutions for considering things in the evaluation of the PL are discussed in this article.

According to the basic machinery safety standard ISO 13849-1, the capability of a machine control system to perform a safety function is expressed using performance levels (PL). The required performance level for a safety function is defined in a machine specific standard or it has to be defined using risk analysis. After ISO 13849-1 standard becoming effective, VTT has made several evaluations for estimating if required performance levels (PL_r) of machine safety functions are fulfilled. The purpose of evaluating performance levels for machine safety functions is to ensure the implementation of safety features in the control system of machinery.

Experiences have shown that the biggest challenges in evaluating the PL of the safety related parts of the control system (SRP/CS) are related to the formulation of the safety block diagrams for these parts and collecting source information for the PL calculations. Different evaluators may construct a safety block diagram for a safety function in various manners. This may lead to different results in the evaluation of the achievable PL. Also the input source of the failure rate data for the calculation has a huge effect on the $MTTF_d$ values. It is still difficult to get information relating to MTTF values of components.

PL estimation

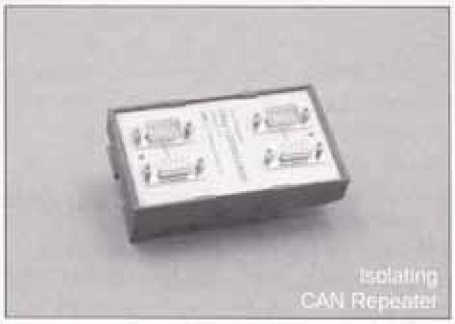
When starting to evaluate the PL for a certain safety function it is important to clear up if the required PL (PL_r) exists for this safety function. PL_r may be expressed in the C type machinery safety standard. If the PL_r is found in the C type standard, it is applied. If the PL_r is not known, it can be estimated using a risk graph method given in ISO 13849-1. After this phase the safety function is to be designed so that the estimated PL_r is fulfilled.

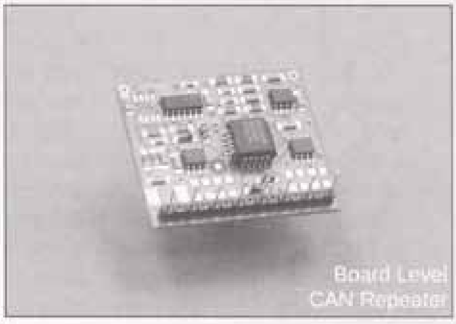
After determining the PL_r for each safety function in a machine control system, a safety block diagram has to be drawn. This is done for each safety function and it consists of only those components that participate in the execution of the safety function. Usually a safety block diagram consists of input (e.g. sensors, limit switches etc.), logic and output (e.g. actuators, contactors etc.) components. The safety function can be either a single or dual channel solution. It is important to notice that the safety block diagram of a safety function may look completely different from the technical realization or, for example, from the functional block diagram. ISO 13849-1 introduces designated architectures, which show a logical representation of the system structure for each category (B, 1, 2, 3 or 4). The category of the SRP/CS should be chosen by the system architect, but in some cases, the category is pre- defined in the safety function specification along with the PL_r. The category also affects MTTF or $MTTF_d$ calculations.

When the safety block diagrams for the safety functions of the control system have been created, the MTTF or $MTTF_d$ values for the parts (components) of the safety functions should be collected. If there is no information available about MTTF or $MTTF_d$ values in the components manufacturers' data sheets (which is a typical case), the values of the ISO 13849-1 standard can be used. For components, the MTTF of which depends on the number of use cycles, the component manufacturer's data sheets may include information on the number of cycles until 10 % of the components of the same type fail dangerously (i.e. the B_{10d} values of components). In this case, $MTTF_d$ for the components can be calculated from the equations given in ISO 13849-1.

The diagnostic coverage (DC) should be estimated for the input, logic and output parts of the safety function. For estimating the DC for these parts, tables in Annex E of ISO 13849-1 are useful to go through. After this, the average DC (DC_{avg}) can be calculated for the safety function implementation and this can be done using the formula given in Annex E of ISO 13849-1. In general, structural principles can be used for avoiding, discovering or tolerate failures. In practice, measures like redundancy, diversity or monitoring can be used. In addition, the diagnostic coverage (DC) should also be at least "low" in order to reach PL d. ▷

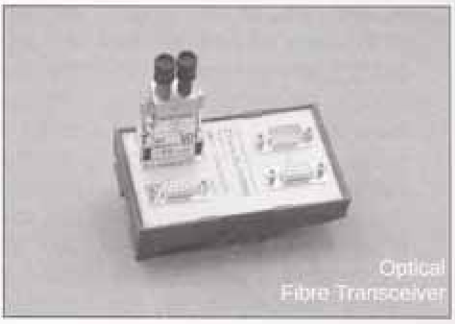

Compact
CAN Repeater


Isolating
CAN Repeater


Board Level
CAN Repeater


Gateway
CAN/CAN


Physical
Layer Analyser


Optical
Fibre Transceiver

The diagnostic coverage could also be estimated using FMEA, in which case the detection of each failure mode should be analysed. Finally, the common cause failures (CCF) for category 2, 3 and 4 structures should be estimated. In addition, software implementation and systematic failures should be assessed following the ISO 13849-1 standard. After carrying out these measures and estimating these parameters, the attainable PL for the safety function of the control system can be defined based on the graph given in ISO 13849-1.

Errors in discrete cabling

Based on a long-term follow-up concerning mobile work machines, typical life time for an instrumentation cable varies between 1 and 3 years. The life time is mainly dependent on the operational environment, not on the signaling type. The failure rate of discrete wiring is higher than that of digital network wiring due to much larger amount of wire [3]. Single-channel discrete I/O-wiring cannot offer any confirmation about the signal validity, which is clearly required in safety related control systems by the standards [10]. An input device can only check, whether the input signal is within the specified range or not. Actual signal sources for analogue signals cannot be identified by the input-device. The actual transmitter may be the signal source, but also any wiring failure may contribute at least part of the signal value.

According to the safety standards, discrete wiring shall be analyzed together with the corresponding subsystem [10]. Certain faults can be excluded only based on detailed justification given in the technical documentation [1]. It is clearly stated that a well-tried component for some applications can be inappropriate for other applications [2]. In machinery applications it means that cables need to be analyzed because of relatively high cable failure rates.

Errors in CANopen networks

One of the main targets of the CAN-communication has been to achieve less than one unrecognized error appearing in average life time of a vehicle [3]. The residual error rate cannot be computed directly by CRC and binomial distribution equations because of the various error detection mechanisms combined in CAN. Local errors are distributed globally, why increasing number of nodes per network decreases the residual error probability [4].

The residual error probability extrapolated from the published curves [5] is equal or less than the result of equation 1. Bit-error probability 10^{-3} [3] and 10^{-4} [5] [9] presented for CAN may be obsolete, because significantly lower values from 10^{-7} down to 10^{-11} are published later, together with the measurement arrangement [6]. Residual errors can be divided into the following categories: loss + masquerade (corrupted ID field maps to another safety critical message), loss + insertion (corrupted ID field maps to a non-safety critical message), loss (corrupted ID field maps to a not used message), and corruption (corrupted data field). Bit errors only in the CRC field are always detected. Subsequently, the CAN protocol executes a retransmission of the message that was corrupted. Retransmissions cause increase in the bus load. This shall be considered when assessing the delay errors and network scheduling.

All messages with corrupted data are potentially dangerous. Messages with a corrupted identifier are dangerous only, if the corrupted identifier corresponds to an identifier used by another valid safety critical message.

The message error probability can be either extrapolated from the curves presented in the literature [5] or computed from Equation 1:

$$P_{ME} = 1\text{-}(1\text{-}P_{BE})^{NBitsInMsg}$$

Where PBE is the bit error probability, PME is the message error probability and NBitsInMsg is the number of bits in a message. Furthermore, the residual error probability PRES for CAN can be computed by Equation 2 [7]:

$$P_{RES} = P_{ME} \text{ x } 4{,}7 \text{ x } 10^{-11}$$

For simplicity, the residual error probability for both corruption and masquerade errors is assumed to be one, which is slightly pessimistic. Thus PMas equals PRES. Finally, the effect of the masquerade errors can be computed based on the number of message identifiers in use – MInUse – and total number of available message identifiers – 2IdSize, where the use of 11-bit identifiers is assumed (see Equation 3):

$$P_{MasEff} = P_{Mas} \text{ x } \frac{M_{InUse} - 1}{2^{IdSize} - 1}$$

The most interesting result is that CAN communication can meet the SIL2 target or even SIL3 with reasonable safety measures, depending on the bit error probability specific to the application environment [7], and provided that the application messages and their protocol are carefully designed to tolerate all the communication error types (loss, insertion, unacceptable delay, unintended repetition, incorrect sequence, masquerade and addressing) besides the bit error caused corruption error (which is manifested as a masquerade, loss or insertion error if the bit error hits the CAN identifier field). The CANopen communication services and device profiles with proper application design tackle most of these error types. Heartbeat consumer and RPDO timeout monitoring are the main CANopen safeguards for signal transfers, covering deletion and timing errors. All detected errors in the CAN-layer are visible as delayed transmissions in the CANopen layer. Also insertions caused by an unspecified device or a configuration error can be detected, when a valid RPDO is received, but the heartbeat of the corresponding producer is missing. The TPDO inhibit time is the main safeguard against repetition. To follow a standardized design process is essential, because all communication is configured based on the system project information. Masquerade errors may be detected in the CANopen layer, if a corrupted message has a different number of data bytes than the corresponding valid message. Tolerance to repetition errors typically need to be verified by performance testing of RPDO- reception.

Case study

The safety function evaluated in the case study was a stopping function of a subsystem which is integrated on a mobile work machine. The PL for the safety related part of the control system that executes the stopping of the sub- system was estimated for three alternative structures, A, B and C. When estimating the PL the following presumptions were made: common cause failures (CCF), software implementation and systematic failures have been analyzed and found to meet the requirements. The subsystem is normally stopped by releasing the joystick to the middle position. The stopping function of the subsystem can also be induced

▷

CiA

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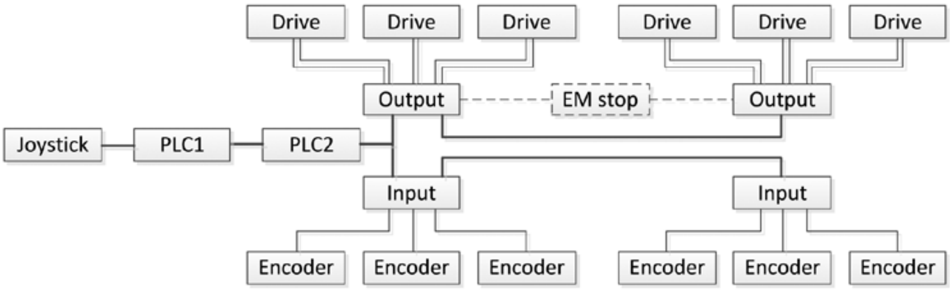

Figure 1: The functional diagram of structure A.

e.g. by exceeding encoder limits. In addition, the sub-system can also be stopped using emergency stop device, which cut off all power from the drives. However, the PL calculations were executed for that case where a stop function is initiated by one of the encoders.

In the structure A, drives are located centralized as one block (Figure 1). There is a hard-wired safety cut-off device in the block. There is an individual I/O (4...20 mA for measurements), which is marked using narrow lines. The broad lines in Figure 1 denote CANopen.

Scaling of measurements and control values as well as control and adjustment calculations etc. are made by PLC2. The safety block diagram for the structure A is presented in Figure 2 for the case where one of the encoders initiates the stopping function.

The structure A is a single channel system and all parts have at least some kind of monitoring. The structure has relatively long analogue cables from the encoders to the input devices and from the output devices to the drives. These cables are sensitive to interruptions since the cables are situated outside of an enclosure and close to an actuator. The monitoring of encoders and their cables can detect a failure, which leads to values outside of the acceptable range. Sometimes water and dirt can cause a partial short circuit, which has acceptable conductance. This means that the diagnostic coverage is poor. The input part of the safety function was evaluated to fulfill the category 2 requirements.

According to a study [11], over 30 % of all failures in mobile work machines are related to cables or hoses. (Calculated from the cable failures, 66 % related to open circuits of sensor cables.) The value is 4 to 10 times higher than the value in stationary production [11]. This means that the cable failures cannot be neglected when mobile work machines are considered.

In the structure B (Figure 3), drives and encoders are like in the structure A. All components connect to the same CANopen network. The filtering and scaling of measurements and control values are realized in encoders and drives. All control and adjustment calculation is executed in PLC2. The safety block diagram for structure B is presented in Figure 4.

The structure B is a single channel system, where all parts are monitored. The structure has no analogue cables and therefore the failures related to them do not exist.

The structure C resembles structure B but the difference is that the drives are integrated into the actuating devices. Only the safety cut-off device is located outside the actuator. CANopen network is implemented like in the structure B. Measurement filtering and scaling is implemented in encoders, and sub-system-specific adjustment is distributed into drives. Manual control is executed by deviating the target position of the sub-system. A redundant limit indication for the movement is implemented using another encoder. The safety block diagram for the structure C is quite similar to as presented for the structure B (see Figure 4). In the structure C solution, software is distributed to encoders

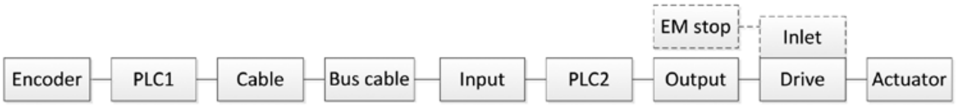

Figure 2: The safety block diagram of structure A, where one of the encoders initiates the stopping function.

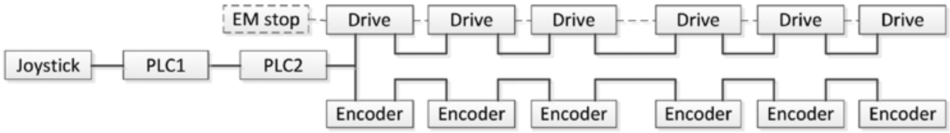

Figure 3: The functional diagram of structures B and C.

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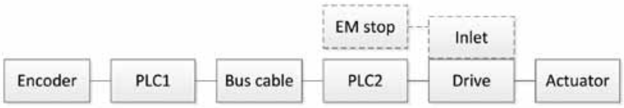

Figure 4: The safety block diagram of structure B, where one of the encoders initiates the stopping function.

and drives more than in the structure B solution.

When comparing the attainable PL for these structures, which represent category 2 solutions, a calculation example was done. The following MTTF_d values for the components were used: 160 years for encoder, 50 years for PLC1, 24 years for input device and 4 years for analogue cables. Analogue cables with an input device were included when calculating the MTTF_d for the input part of the structure A safety function. Using these values, the MTTF_d of 3 years (low) for the input part of the structure A was got as a result. If the DC_{avg} is “low”, the reachable PL in this case is “a”, and it would not increase if the DC_{avg} is improved from “low” to “medium”. CAN cables were not included into calculations, because failures in CAN cables typically result in the situation in which there is no communication.

The corresponding calculations with the same MTTF_d values for components were made to the input part of the structure B safety function, removing analogue cables and an input device from the calculations. Now, the MTTF_d for the input part of the structure B safety function is 38 years (high). If the DC_{avg} is “low”, the reachable PL in this case is “c”. The reachable PL would be improved to even “d”, if the DC_{avg} could be increased from “low” to “medium”. Similar kinds of results were detected when calculating MTTF_d values and PL’s for the output parts of the structures A and B. There is no difference in the PL calculations between structures B and C safety functions, if the same MTTF_d values are used for the components. ◄

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Analyzing the performance of CAN networks

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CAN networks are usually determined by their communication matrices (communication table). There are various configuration tools that facilitate the input of the necessary data and can even generate the communication stack for control units (ECU: Electronic Control Unit). The design of communication tables is often over-determined. For automotive industry applications this means that the configured messages and signals describing an entire vehicle platform would not be built and integrated in one single car that way. But as this "150 %" model contains all occurring variants, it makes a good starting point for timing analysis.

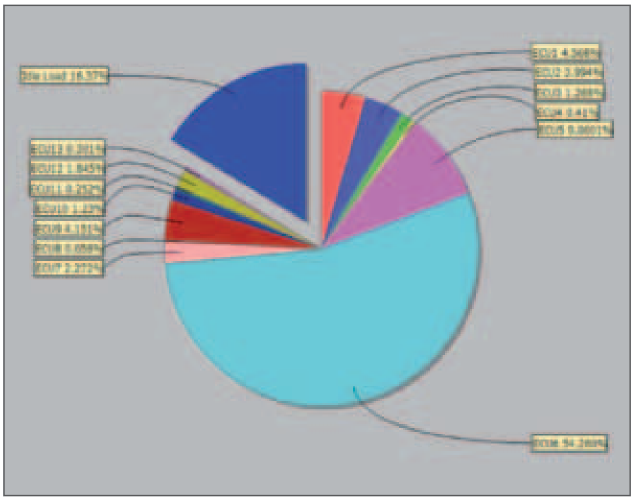


Figure 1: Load per ECU

Periodic load

The first step in CAN network performance analysis usually focuses on the observation of purely periodic messages. This approach neglects all sporadic activations and carries out a preliminary study concerning load and response times. The period for each periodic message is usually used as the message deadline. If there is more information about the message deadline, then of course this information can also be entered.

Figure 1 shows the total load of an example CAN network and its load shares for each connected ECU. Focusing on the response times for each message and comparing them with

▷

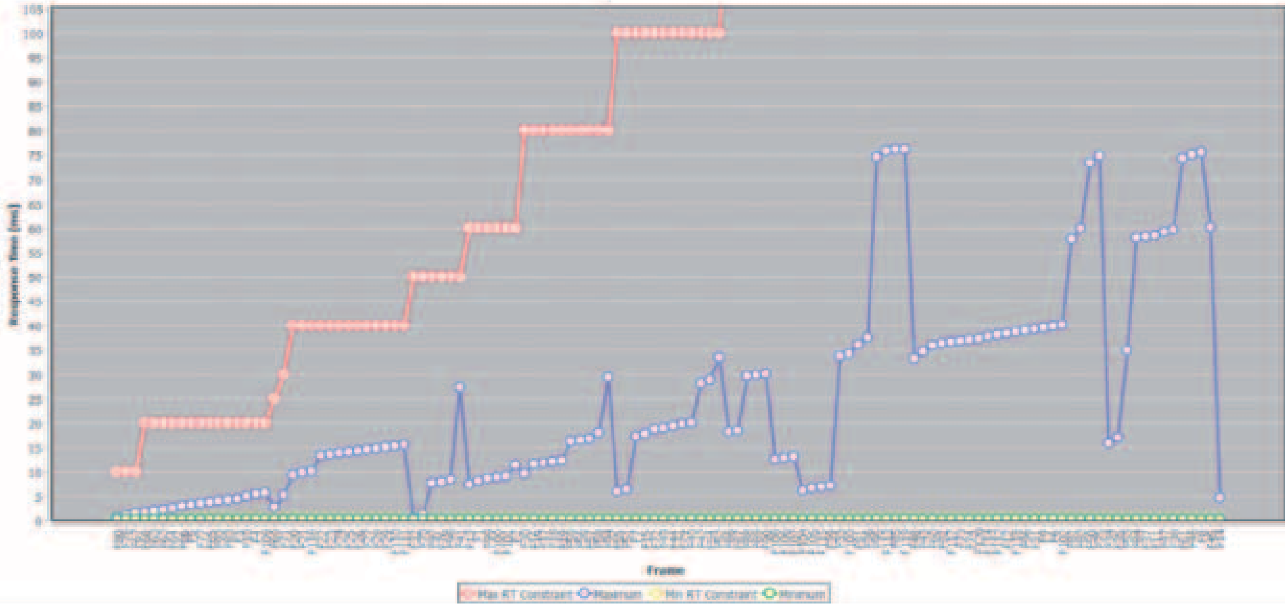
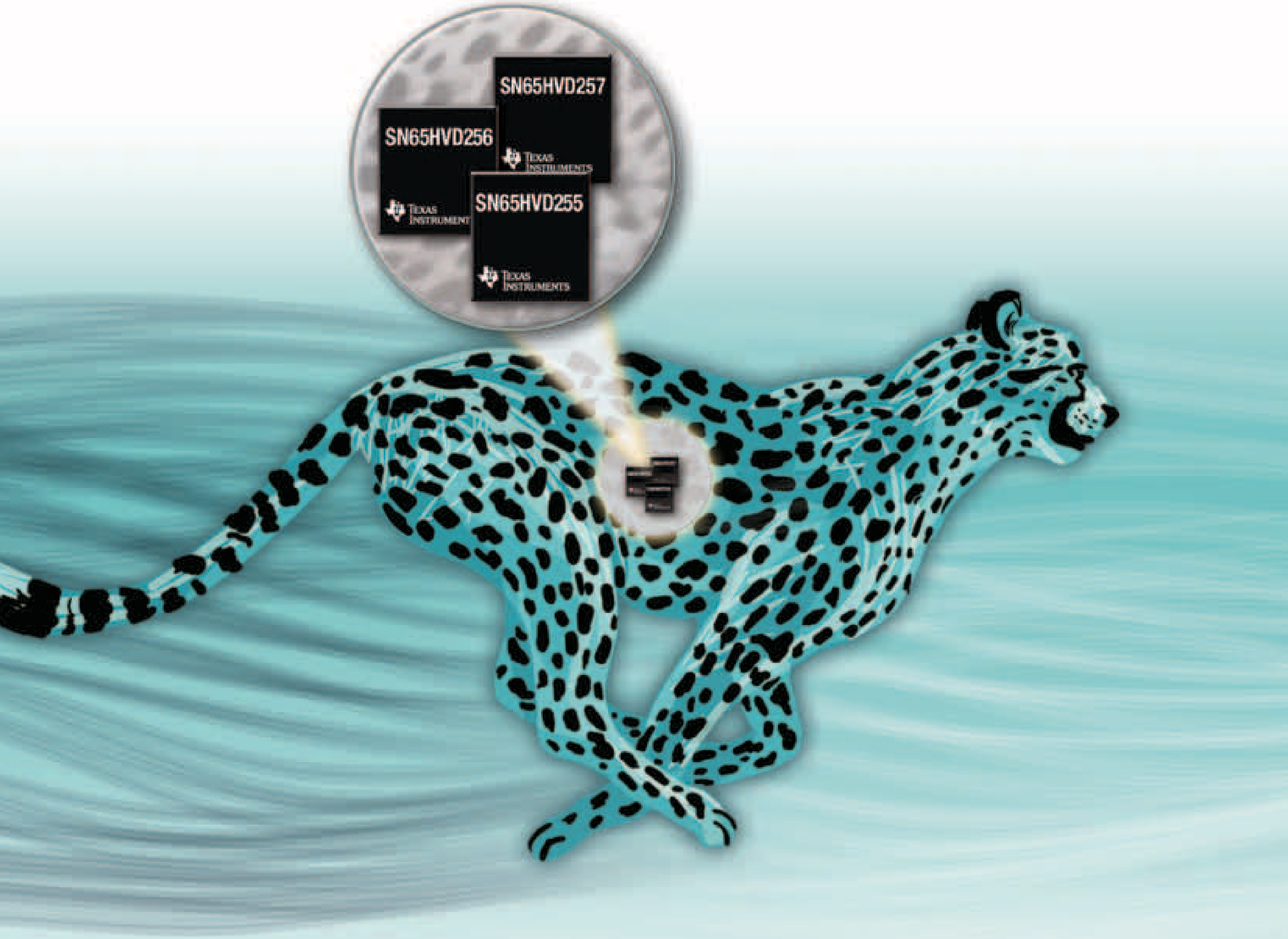
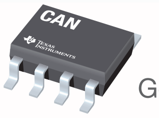


Figure 2: Response time profile for periodic messages only



SN65HVD257
SN65HVD256
SN65HVD255
Texas Instruments



CAN
Texas Instruments

Introduction

CAN's wide-spread use has ensured that it is constantly being improved and updated, for example, with the introduction of CAN-FD. Most developments have related to increasing transmission rates to improve data throughput and, consequently, performance in order to meet the integration requirements of demanding new application features and functions. The most commonly used metric to determine CAN bus performance is the load. Usually a value of between 30 % and 50 % is used to guarantee trouble-free communication. The simplicity of this metric is what promoted the early acceptance and adoption of the CAN and was certainly more than adequate in the early days. Meanwhile, the emergence of timing analysis tools, with their ability to resolve much more extensive and more reliably indentified timing problems, has enabled the focus on load to be shifted into the background.

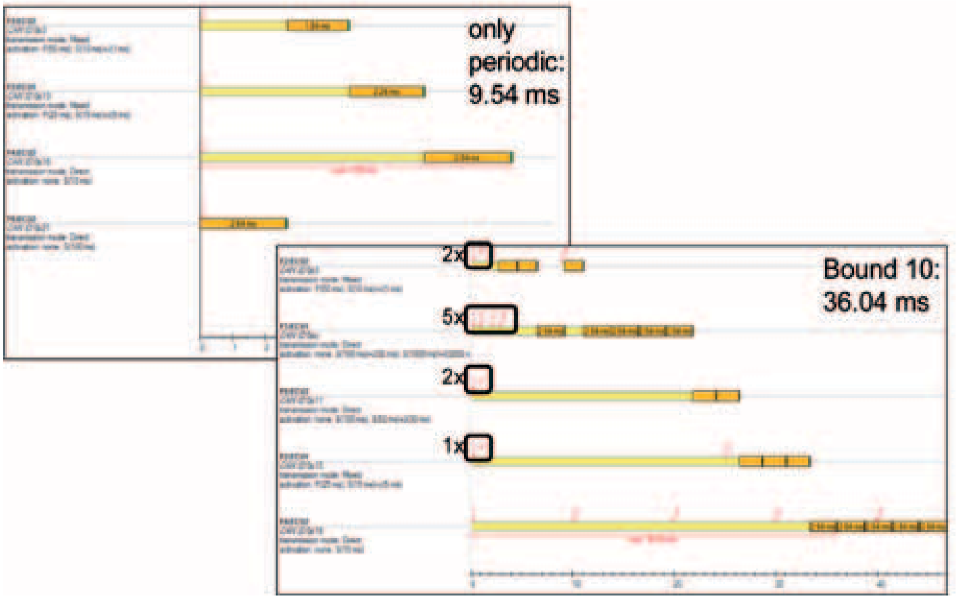


Figure 3: Response time comparison for only periodic and "Bound 10" sporadic activations

their related deadline, leads to the response time profile shown in Figure 2.

The y-axis shows the analyzed response times (minimum and maximum) and the deadline in [ms] for each message where the x-axis represents the message itself. The values are sorted by the deadline, which is represented as a red curve in the graph, but is cut-off for messages with a deadline longer than 105 ms for a better overview (zoomed in). The blue curve represents the calculated worst case response time of each message, the green curve shows the analyzed best-case response time.

Figure 2 shows that despite a high busload of about 83 %, no time-critical problems occur since no deadline is violated. Thus, an assumption that a high busload does not necessarily lead to timing problems is confirmed here by practice. It should be noted however, that this chart still does not

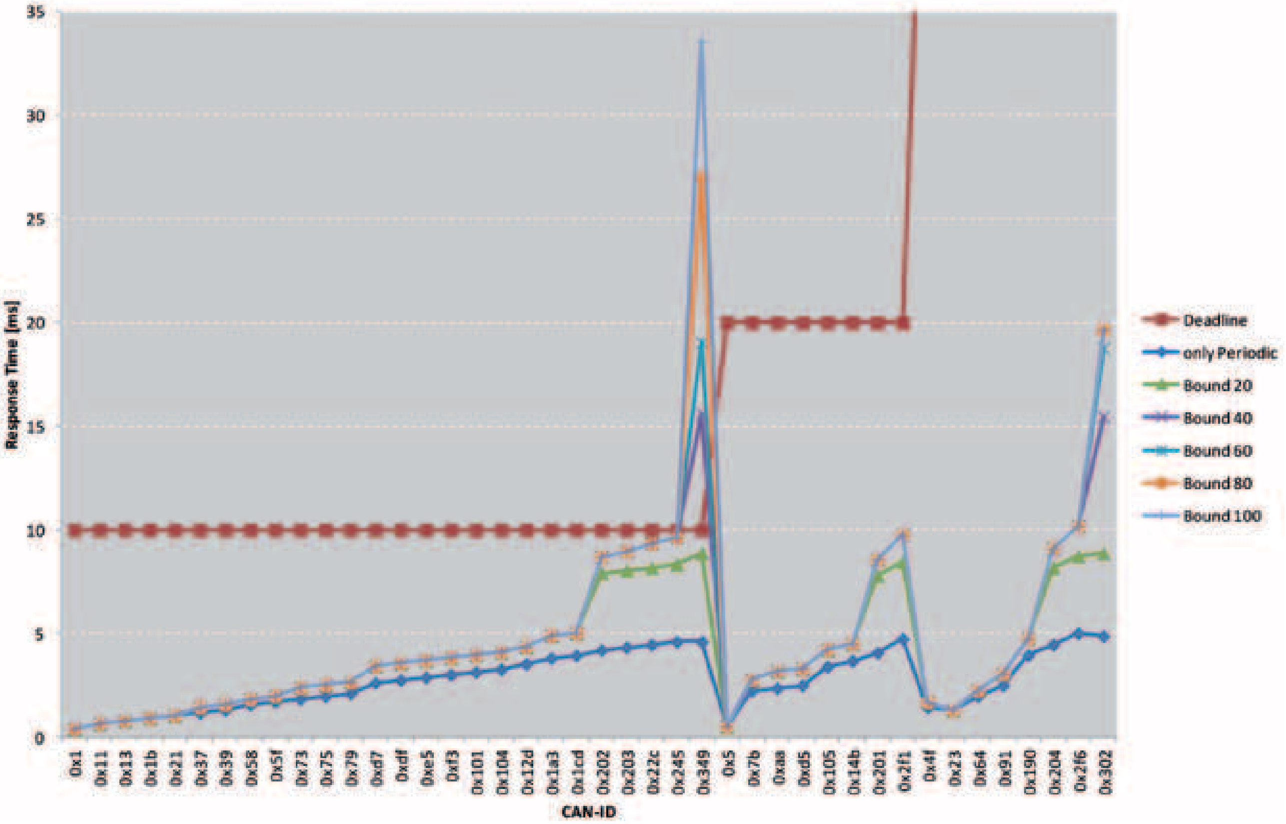


Figure 4: Response times for different "Bound" values

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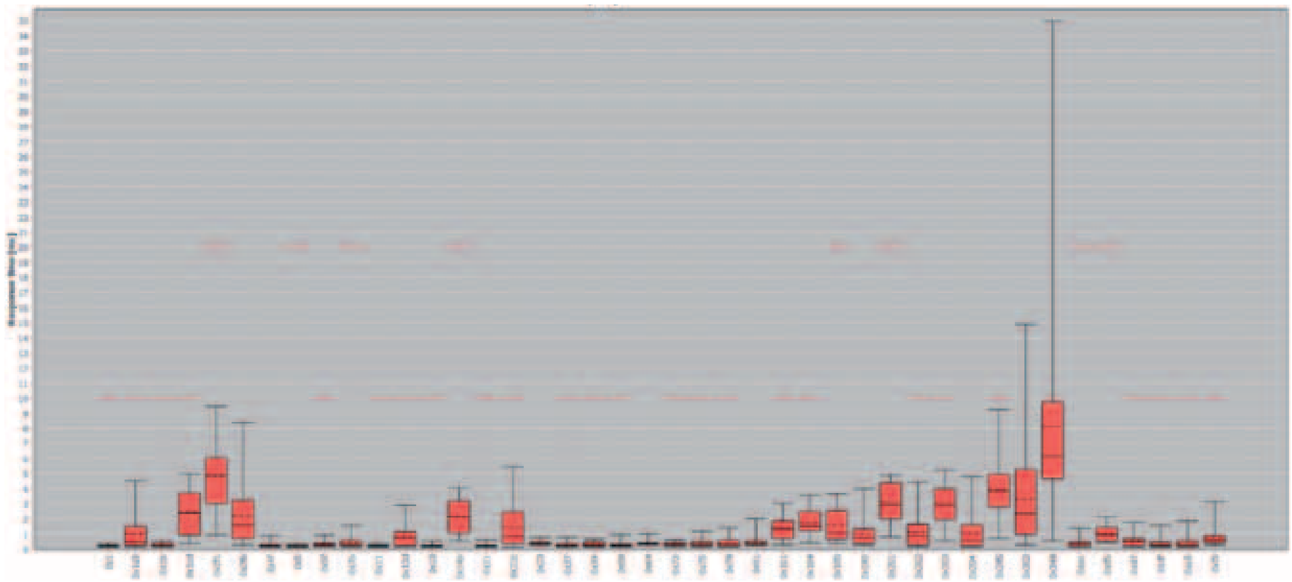

Figure 5: Response time box plot of System Distribution analysis results

Such timing issues include occurring delays and related deadline violations, large jitters which may reduce the quality of a controller and the age or loss of data. There are a number of other real-time criteria, but they will not be considered here.

This article focuses on the operation of timing tools, for CAN bus analysis and highlights the resulting analysis metrics that are best for evaluating CAN bus performance. It also touches on optimization potential and provides a view on future technologies and their evaluation possibilities.

consider the sporadic activations, which will be considered in the next section.

Sporadic load

This "relaxed" position changes, if sporadic load is added to the pure periodic load. Sporadic loads typically result from event-driven activations such as operating the window up/down button, tuning the radio volume, switching a light on and off, or stepping on the brake pedal activating a stop light. Many of these sporadic activations are non-deterministic, hence events that are not clearly defined by pre-conditions. This makes it nearly impossible to predict or analyze accurate bus loads or message response times.

Symtavision has addressed this problem and created a solution that can predict worst case results very accurately, enabling the easy dimensioning and parameterization of the communication matrix. The approach considers and uses the minimum transmission distance of each frame, also called "debounce value" or "message delay time". This value specifies the maximum frequency or minimum period a message on the bus can be transmitted, regardless of which activation scenarios are applied to send the message.

Thus, the activation of a CAN message can be composed of two components: the purely periodic part and a sporadic part that is used for worst-case analysis as an additional periodic activation corresponding to the maximum limit.

Autosar defines 4 different transmission modes for CAN messages, which implicitly result from the activation scenarios:

- None: the message is not transmitted or activated
- Periodic: the message is purely periodic without any sporadic shares
- Direct: the message has only sporadic activations
- Mixed: the message has periodic and direct activations

Figure 3 shows that low priority messages can be transferred delayed by the occurrence of sporadic activations (event-triggered) of high priority messages. The graph illustrates the requested and actually transferred message in each row. The transmission request is listed as a numbered red arrow, the actual message transmission as a dark orange area. The light yellow area shows the blocking period.

Although the concentration on only one Bound value already has some validity, it is better to do several analyses for different bound values and to compare them afterwards. As a result, you get a better assessment of the effects of sporadically activated messages. Figure 4 illustrates result examples of this procedure.

The curves shown in Figure 4 clearly show the critical region in the central part of the graph. The red curve is the deadline of a message which is equal to the message period. For purely periodic messages (dark blue curve) and also for 20 sporadic activations (Bound 20, green curve) no deadline is violated. It becomes critical for the message 0x349 that violates its deadline for Bound values above 20. Other messages also come pretty close to their deadline.

Criticality evaluation

With "Worst-Case" scenarios customers often ask: "How often does it happen?" To answer this question, Symtavision has implemented a System Distribution Analysis capability, which varies the input stimuli by performing many short simulation runs and processes the collected timing data analytically. System Distribution Analysis randomly varies the initial activation offset between non-synchronized frames compared to worst-case analysis, which calculates them to maximize the message response time latency. In addition, the message periods can be varied, so that the physical phenomenon of "clock drift" is simulated. As a result of this Monte Carlo simulation, statistical data is obtained on the response time with the typical characteristics of minimum, maximum, median, mean, upper and lower quartile. These values are shown typically in the form of box plots (also called box-and-whisker). Figure 5 shows such a box plot, in which the graph additionally displays the deadline as a short red horizontal line for each CAN message.

Focusing on the critical message (CAN-ID is 349_h, the seventh message from the right), it is easy to recognize in the box plot that over 75 % of response times are below the deadline (upper quartile, also called Q3, is below the deadline).

The cumulative graph provides a more detailed representation for the selected message. There, the occurrence probabilities of each response time are integrated over time and shown in comparison to the deadline which indicates the probability for deadline violations and supports reading the value directly. Figure 6 shows a deadline compliance of 82,274 % for the message with the CAN-ID 349_h.

Summary and outlook

If a critical timing situation is found, further questions come up, such as: How can this situation be avoided? Or: Which options for optimization do we have? Furthermore, you may want to compare the analysis results to trace data or possibly refine the sporadic activation pattern based on trace data. Symtavision also provides opportunities for these situations, but these would be the subject of another article.

It is obvious, therefore, that considering bus load only is not sufficient to evaluate the CAN bus performance in terms of its real-time capabilities. For this purpose, the response times of the CAN messages must also be considered, which can be determined by the method outlined above. This can also be done at a very early stage in development.

This enables a communication matrix to be secured at an early development stage, thus saving time and costs. Certainly this procedure does not replace HIL/MIL/SIL tests or live tests in the vehicle or the machine used, but it contributes significantly to the stability of a communication matrix and offers the potential for additional test case generation.

Curtain up for CANopen stage drives

Introduction

The works of Beckett and Brecht, Mozart and Wagner, and of course Goethe and Shakespeare are all performed on the stage of Theater Duisburg (Germany). After decades or even centuries, these plays, concerts, and operas continue to fascinate the audience. The drive technology for the stage, however, had seen better days and therefore, the theater had installed new electrical equipment for backstage technology. Hoists, rods, and other proven mechanical components as well as most existing geared motors continue to perform their duties, but are now controlled by a system from Unican specialized in equipping theaters. The high-availability stage automation system is a solution that fulfills the requirements of SIL 3 according IEC 61508. It includes HMI consoles, software, and application-tailored enclosures with axis controllers by Nord Drivesystems that are connected to dozens of drive units via frequency inverters.

Link

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Hand-operated spotlights, curtains, and stage elements are no longer common in opera houses and theaters. Today, complex automation technology and many drive units ensure that heavy scenery objects are moved to change sets at the right time during a show, spotlights are repositioned again and again, and sound and video systems are operated synchronously. Unican is one of few manufacturers of extensive automation-based operating and control solutions for all types of theater stages. The OpenCue software solution provides opera houses, theaters, congress centers, and similar facilities with a modern system featuring fixed or mobile operating consoles. The HMI units and their graphical interfaces allow for easy access, continuous monitoring, and versatile show programming of up to 240 drives in the upper and lower machinery area of stages. In opera houses and theaters, operating many hoists and other machinery in the vicinity of artists, technical staff or even the audience is practically unavoidable. This often involves the lifting or moving of heavy loads, which further increases the risk potential. Safety measures to prevent serious accidents are therefore mandatory. In most cases, the safety-relevant electrical components must ensure safety integrity level SIL 3 according to IEC 61508.

Figure 1: Each enclosure contains one ICU computer by Unican (bottom left) and an SK 535 frequency inverter by Nord (top right)

More than one hundred drives

This safety requirement also applied to the new systems for the Theater Duisburg. All in all, 74 drives in the so-called upper machinery (that is, drives used to move rope and chain hoists above the stage area) and 39 drives on six podiums and slopes in the lower machinery were modernized. ▷

Figure 2: After a modernization, stage technology at Theater Duisburg is now mainly operated by means of fixed OpenCue consoles with two 22-inch touchscreens

For the control solution, Unican installed three operating consoles: two with double 22-inch screens and one with a single 19-inch screen. The screens can be operated in an upright position or lying on the console. Input options are the touchscreen display and the keyboard integrated into the aluminum console, which features various backlit special keys, two joysticks, and a trackball. In addition to these fixed stations, the system house also delivered a handheld HMI with a 12-inch touchscreen. The largest part of the system installation, however, was taken up by customized enclosures for the more than one hundred drives, each of which is equipped with a host-computer from the ICU series by Unican. These electronic units operate regardless of the type of connected drives and can therefore be used to control hydraulic and pneumatic solutions as well as electric ones. The controllers feature a double CAN interface supporting CANopen, and are equipped with two inputs for SSI encoders and an integrated emergency stop relay. The host controllers are available as dual channel versions for SIL-3 applications.

Reliable frequency inverters

At Theater Duisburg, the host computers control the electric motors. For that purpose, each of the more than one hundred customized enclosures is equipped with an CANopen-connected SK 535 frequency inverter from Nord Drivesystems. The stage drives required reliable power electronics that could seamlessly fit into the safety concept.

All inverters feature integrated brake management, a brake chopper and a line filter as well as sensorless current vector control. Even the basic model, which is equipped with five configurable control inputs, two analog inputs, one analog output, and two relay outputs, provides a wide range of connection options. For Theater Duisburg, SK 535E models in sizes 5 and 6 with an 11-kW and 22-kW performance were chosen from the SK 500E series, which is currently available with rated motor outputs up to 90 kW. In addition to the basic features described above, these models also feature two digital input and two output channels and a TTL input for speed and torque control. Moreover, they feature a “Safe Stop” function in compliance with EN 954-1 and EN 13849-1 (up to safety category 4, stop category 0 and 1) and come with an on-board CANopen interface. A Posicon module that provides positioning control functions is also included in delivery. Furthermore, the controller card of the drive can be powered from a separate 24-V supply, allowing access to parameter data and the bus interface even if the mains power is switched off. This enables specific applications such as elevator evacuation and increases online availability.

Figure 3: The safe control solution includes customized enclosures for each of the more than one hundred drives in the upper and lower machinery

Holger Zeltwanger

Nord Drivesystems

The drive manufacturer employs some 2900 people. The portfolio ranges from standard drives to customized solutions, e.g. based on energy-efficient or explosion-protected drives. Gross sales amounted to 450 million € in 2012. Founded in 1965, the company has grown to include over 35 subsidiaries. The company offers also gear and motors as well as frequency inverters. the inverter line-up features conventional models for installation in control cabinets as well as design types for integrated drive units with network interfaces, e.g. CANopen.

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Summary

With the described automation technology controlling more than one hundred drives in the upper and lower machinery, Theater Duisburg has been equipped with a system solution that fulfills the safety requirements of SIL 3. The system enables easy operation as well as the programming of complete performances on touchscreen operating consoles. Numerous customized enclosures for the stage drives – which provide a functionally safe connection between the partially modernized electric motors and the state-of-the-art control system via new frequency inverters – are the core component of the electric equipment.

Using 3,3-V transceiver

Jason Blackman, Scott Monroe

Author
Jason Blackman
Scott Monroe
Texas Instruments

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Abstract

3,3-V transceivers offer advantages and flexibility with respect to 5-V CAN transceivers while being compatible and interoperable with each other. Power consumption is lower with 3,3-V transceiver. Some CAN users may be skeptical to apply 3,3-V transceivers due to the legacy of 5-V transceivers that are known to perform well. There may be uncertainty of performance in mixed supply CAN network. This article describes the interoperability of both kinds of CAN transceivers. In addition, the theory of operation is explained.

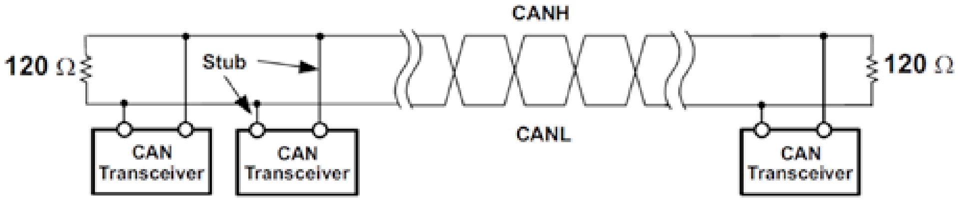

Figure 1: Typical CAN network

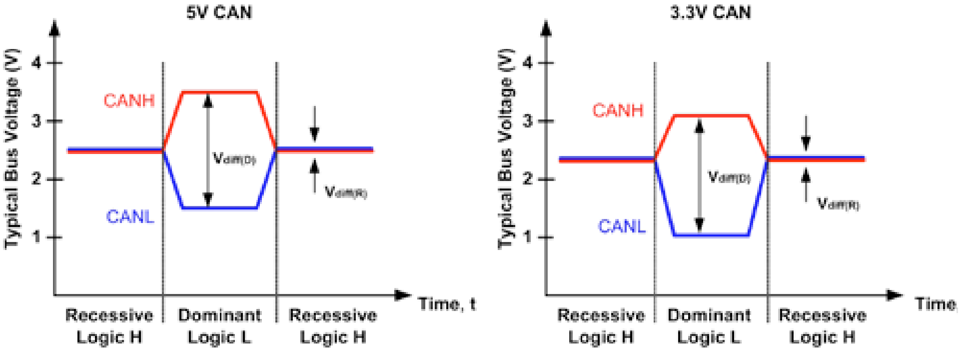

Figure 2: Typical CAN bit-levels for 5-V (left) and 3,3-V (right) transceivers

The ISO 11898-1 specification details the physical layer requirements for CAN communications. CAN is a low-level communication protocol over a twisted-pair cable, similar to EIA 485. The high-speed physical layer is specified in detail in ISO 11898-2.

An important feature of CAN is that the bus isn't actively driven during logic 'High' transmission, referred to as recessive state. During this time, both bus lines are typically at the same voltage, approximately half of V_{CC}. The bus is only driven during 'dominant' transmission, or during logic 'Low.' In dominant state, the bus lines are driven such that $CAN_H – CAN_L$ ≥ 1,5 V. This allows a node transmitting a 'High' to detect if another node is trying to send a 'Low' at the same time. This is used for non-destructive arbitration, where nodes start each message with an address (priority code) to determine which node will get to use the bus. The node with the lowest binary address wins arbitration and continues with its message. There is no need to back-off and re-transmit like other protocols.

CAN receivers measure differential voltage on the bus to determine the bus-level. Since 3,3-V transceivers generate the same differential voltage (≥ 1,5V) as 5-V transceivers, all transceivers on the bus (regardless of supply voltage) can decipher the message. In fact, the other transceivers can't even tell there is anything different about the differential voltage levels.

For 5-V transceivers, CAN_H and CAN_L are weakly biased at about 2,5 V ($V_{CC}/2$) during recessive state. The recessive common-mode voltage for 3,3-V transceivers is biased higher than $V_{CC}/2$, typically about 2,3 V. This is done to better match the common mode point of the 5-V transceivers, and to minimize the common mode changes on the bus between 3,3-V and 5-V transceivers. Since CAN was defined as a differential bus with wide common mode allowing for ground shifts (DC offsets between nodes) this isn't needed for operation, but will minimize emissions in a mixed network. In addition, by using split termination to filter the common mode of the network a significant reduction in emissions is possible. The ISO 11898-2 standard states that transceivers must operate with a common-mode range

▷

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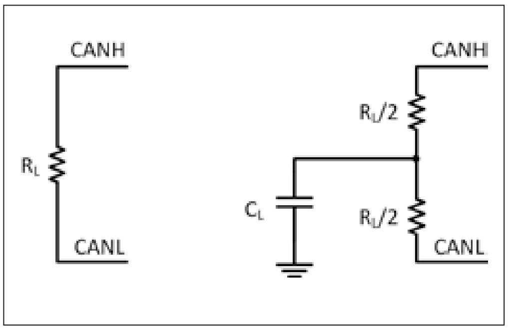

Figure 3: Single termination (left) and split termination (right)

Figure 4: Waveforms of two 5-V SN65HVD255 transceivers by Texas Instruments

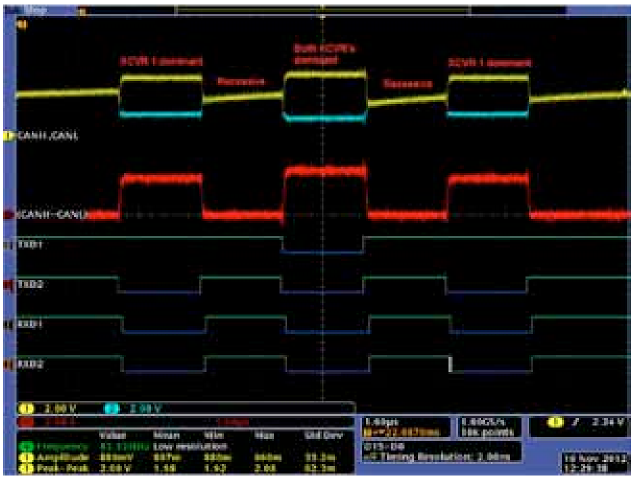

Figure 5: Waveforms of two 3,3-V SN65HVD234 transceivers by Texas Instruments

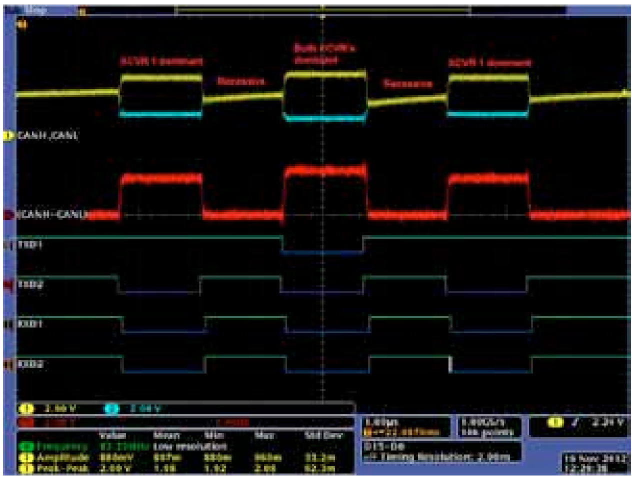

Figure 6: Waveforms of two SN65HVD255 transceivers, one with a +1-V ground shift

of -2 V to 7 V, so the typical 0,2-V common-mode shift between 3,3-V and 5-V transceivers doesn't pose a problem.

Figure 4 shows two 5-V transceivers communicating on the same network. The signals TXD1 and TXD2 show what each transceiver is driving onto the bus, while RXD1 and ‘RXD2 indicate what each transceiver is reading from the bus. The two upper signals are the bus lines, CAN_H (yellow) and CAN_L (light blue). The red waveform below them is the calculated differential voltage between CAN_H and CAN_L.

A simplified bit pattern was used to demonstrate the CAN principles. Bit time 1: one transceiver transmits a dominant bit while the other remains recessive. Bit time 2: both transceivers are recessive. Bit time 3: both transmit dominant, showing what would happen during arbitration. As shown the differential voltage is slightly greater when both transceivers are dominant due to the output transistors of each transceiver being in parallel, resulting in a smaller voltage drop and greater differential voltage output.

Figure 5 shows the same setup but with two 3,3-V transceivers (TI SN-65HVD234). The differential voltage between the bus lines during dominant bits is lower than the 5-V components that were tested, but this still meets the requirements of the ISO 11898-2 standard. In addition, the guaranteed minimum differential bus voltage for the 5-V components is the same as with the 3,3-V components (1,5 V). This means that designers have no advantage if choosing 5-V components for their higher differential driving abilities, since there is no guarantee that the differential output will be higher.

Figure 7 shows the same situation as the Figure 6, now with split termination instead of traditional single termination. Split termination, illustrated in Figure 3, helps filter out high frequency noise which can occur when there are ground potential differences between nodes. The setup for Figure 6 used a CL of 4,7 nF.

Figure 8 demonstrates the communication with mixed transceivers. As before, the digital signals TXD1, TXD2, RXD1 and RXD2 show that both transceivers are accurately talking to each other and there is little common mode shift during the communication in contrast to the 5-V homogeneous network with a 1-V ground shift. Figure 9 shows a CAN data frame in a mixed network.

The 3,3-V CAN transceiver families have been successfully tested by the C&S group (Germany) using the GIFT/ICT CAN High-Speed Transceiver Conformance Test. This testing covers a homogeneous network of all 3,3-V transceivers and a heterogeneous network where four out of sixteen CAN nodes are the 3,3-V transceiver and the remaining twelve CAN nodes are a mix of three other "golden" reference, 5-V CAN transceivers by NXP. Both TI 3,3-V CAN transceiver families suc-

Figure 7: Waveform of two 5-V SN65HVD255 transceivers with split termination, one with a +1-V ground shift

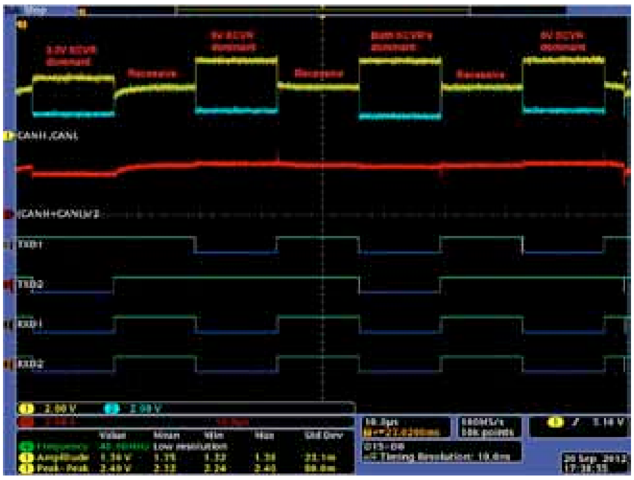

Figure 8: Waveforms of a 5-V SN65HVD255 and a 3,3-V SN65HVD234

Figure 9: Bus communication of a 5-V SN65HVD1050 and a 3,3-V SN65HVD230

Table 1: Chart of supply current for three different 2-node networks

Case 1: 2X SN65HVD234	SN65HVD234 #1 ICC (mA)	SN65HVD234 #1 ICC (mA)
Both recessive	7,1	7,2
#1 dominant	38,4	7,2
Both dominant	25,9	26,1
Case 2: 2X SN65HVD255	SN65HVD255 #1 ICC (mA)	SN65HVD255 #1 ICC (mA)
Both recessive	18,6	18,6
#1 dominant	61,8	18,4
Both dominant	44,6	44,8
Case 3: Mixed	SN65HVD234 ICC (mA)	SN65HVD255 ICC (mA)
Both recessive	7,2	18,6
SN65HVD234 dominant	38,6	18,6
SN65HVD255 dominant	7,2	61,8
Both dominant	11,7	58,9

cessfully passed this testing with no findings.

Using 3,3-V transceivers requires less power consumption. They need lower voltage, and they require also less current (see Table 1).

Table 1 indicates that the supply current for 3,3-V components is reduced by nearly half. Combined with the already lower supply voltage, this results in significant power reduction.

Several other advantages emerge when using 3,3-V micro-controllers. The digital I/O of a 5-V transceiver would be level shifted either externally or in the 5-V CAN transceiver to avoid damaging the micro-controller (unless it is 5V tolerant) where as a 3,3-V transceiver could be directly connected to this micro-controller. The SN65HVD233/234/235 transceivers have 5-V tolerant inputs so they may be used directly with a 3,3-V or a 5-V micro-controller.

If 5 V was only used in the system for CAN, a 3,3-V CAN transceiver would eliminate the need for the 5-V power supply, simplifying the power domains and l owering the cost. ◀

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2. 10 - 49 employees
3. 50 - 99 employees
4. 100 - 999 employees
5. 1 000 - 9 999 employees
6. 10 000 - 99 999 employees
7. more than 100 000 employees

CAN Newsletter

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Position (see A) Application (see C)

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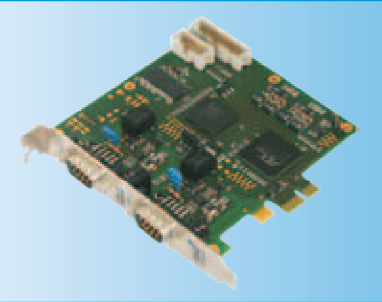
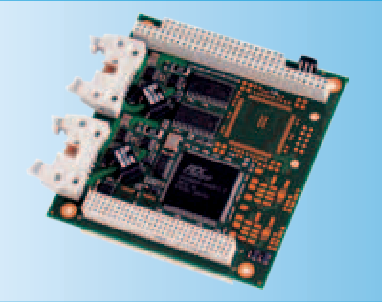
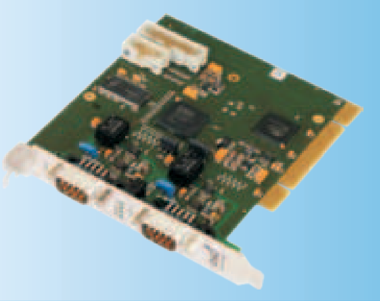
CAN-PCIe/400



PCI-104



CAN-PCI/400



Ethernet

CAN-USB/2

Gateways

All you CAN plug

CAN-PCIe/400

- PCI Express-CAN interface
- High performance CAN interfaces
- Local intelligence based on esd-ACC
- Data transfer rates up to 1 Mbit/s
- Electrically isolated
- Provides high resolution hardware timestamp

CAN-PCI104/200

- PCI104-CAN interface
- One or two independent CAN interfaces for PCI104 bus
- Data transfer rates up to 1 Mbit/s
- Electrically isolated
- DeviceNet option available

CAN-PCI/400

- High performance CAN interfaces
- Local intelligence based on esd-ACC
- Data transfer rates up to 1 Mbit/s
- Electrically isolated
- Provides high resolution hardware timestamps

EtherCAN

- 10/100 BaseT Ethernet-CAN Gateway
- Ethernet protocols: TCP/IP, Modbus/TCP
- Data transfer rates up to 1 Mbit/s
- Configuration and Diagnostics by WEB Browser

CAN-USB/2

- CAN-USB interface
- Intelligent CAN interface with ARM 7
- USB 2.0 high speed interface with data rates of 480 Mbit/s
- Data transfer rates up to 1 MBit/s
- Electrically isolated
- Provides high resolution hardware timestamps

CAN-CBX-I/O

- CANopen Input/Output Modules with In-Rail-Bus
- Connection of CAN and supply voltage without wiring effort
- Data transfer rates up to 1 Mbit/s
- Electrically isolated

Gateways

- EtherCAT-CAN
- PROFINET-CAN
- PROFIBUS-CAN
- PROFIBUS-DeviceNet
- EtherNet/S7-CAN

Operating Systems

esd supports the real-time multitasking operating systems VxWorks, QNX, RTX and others as well as Linux and Windows 32Bit/64Bit systems

CAN Tools

- CANreal: Display and recording of CAN message frames
- CANplot: Display of online/offline CAN data
- CANrepro: Replay of pre-recorded CAN message frames via esd CAN interface
- CANscript: Python scripting tool to handle CAN messages
- COBview: Effective CANopen tool for the analysis/diagnostics of CANopen nodes

The tools are free of charge on the driver CD or can be downloaded at www.esd.eu

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