March 2012 B 25361

CAN Newsletter

Hardware + Software + Tools + Engineering

Partial deactivation of CAN nodes

Power saving in CAN applications

Partial networking for road vehicles

Energy efficiency


NMEA 2000
J1587 | J1708
CAN Aerospace
ARINC
ISOBUS inside
ETHERNET
CANopen
J1939

A personal review

Holger Zeltwanger

It was in 1991, at the Systems exhibition in Munich (Germany), when several companies had introduced board-level products with CAN interfaces. I was in those days the editor of the German VMEbus magazine. Discussing with the CAN module manufacturers compatibility issues, I understood that even the physical layer was different. Most of them had implemented a modified EIA 485 circuitry. Back in my office, I studied the CAN protocol in more detail and was fascinated by this robust and reliable communication protocol. I decided to invite some companies for a meeting to discuss the compatibility issues, and I rented a meeting room in a hotel close to my home. Although I had invited just a view companies for the meeting held in January 1992, 23 parties showed up. Of course, the rented room was too small. Nevertheless, we discussed in this meeting not only the physical layer compatibility problem, but also the need for a standardized application layer. All participants were German. This might be the reason, why we decided to legally form a nonprofit association. The participants asked me to organize a follow-up meeting and to prepare the foundation of a nonprofit association in accordance with German laws.

In March 1992, we established the CAN in Automation users' and manufacturers' group as a non-profit association. I was elected as member of the board of directors and charged to operate the CiA office. In fact, it was a home office. As an editor, I had the idea to publish a newsletter about CAN technology. Already in June, just three month after establishing the CiA, the first issue of the CAN Newsletter was released. It was a copied newsletter with just a few pages. Today it is a well-established printed magazine, and the CAN Newsletter Online is just introduced.

The early days of CiA: In mid of the 90ties, CiA organized joint stands at the Hanover Fair Industry demonstrating the usage of CAN and CANopen in industrial applications (this photo shows some exhibiting member on the CiA booth of 1995)

The CiA organization grew slowly. Not so the work: The members decided to exhibit it jointly on the Interkama 1992 fair in Duesseldorf (Germany). And more, they decided to demonstrate interoperability of their CAN products. Additionally, the inquiries to the CiA international headquarters increased quickly. The work for CiA captured most of my free times in the evenings and at the weekends. But I still worked full-time at home as an editor. Together with my wife and my older daughter (she was a child of just six years) we watched TV and enveloped letters ▷

Entering vertical markets: Nowadays, CiA joint stands are only needed in vertical markets such as the shown booth at the Interlift 2011 in Augsburg (Germany), the world largest event for lift/elevator suppliers

Milestones

1992: CAN Newsletter
1992: Joint stand at Interkama
1992: CiA 102 (physical layer)
1993: CiA 200 series (CAL)
1994: Joint stand at Hanover Fair
1994: First iCC
1994: CiA 301 (CANopen)
1995: Office in Erlangen
1995: 100 members
1995: CiA 401 (I/O profile)
1997: CiA 402 (drive profile)
1997: 200 members
1998: CANopen product guide
1998: CANopen product certification
1999: 300 members
2001: CiA 304 (CANopen-Safety)
2003: 400 members
2003: Office in USA
2003: CiA 417 (CANopen-Lift)
2008: Office in Nuremberg
2008: 500 members
2009: Office in India
2011: Office in China

20 years CiA

Author
Holger Zeltwanger
CAN in Automation e. V.
CiA managing director
headquarters@can-cia.de

In 1992, Holger Zeltwanger initiated the establishment of the non-profit CiA organization. Since 20 years, he is a member of the CiA board of directors. He leads the ISO task force "CAN", and he is member of several other working groups in ISO and IEC.

Links
www.can-cia.org
www.can-newsletter.org

(email was not widely used in those days) and the CAN Newsletter. In 1994, I organized the first international CAN Conference with about 200 participants - still without any secretary or backup office.

In 1995, I rented an office in the neighbor village and hired a half-time secretary on a freelancer basis. It was Gisela Scheib, who is still working with CiA, and many of you know her. The CiA association grew constantly. I tried to avoid any involvement in the so-called "fieldbus war". As an editor, I knew most of the German editors in the field of electronics and automation. This might be a reason, why CiA has bypassed the "war". Another reason was that CiA had not tried to standardize its CAN Application Layer (CAL).

The increasing number of CiA members put more burdens to the CiA office. So, CiA hired more staff. Today we are 14 employees in the CiA office, which is nowadays a real international headquarters. In the 20 years history, CiA operated also offices in the USA, in India, and in China. The Chinese representation office established last year is still in operation. The others have been closed. To be serious, I am in favor of decentralized organizations with highly responsible individuals. But this requires a lot of daily co-ordination and discussions; otherwise efficiency decreases dramatically. The time difference to Europe was one problem and that in other countries the companies do not behave as altruistic as in Central and North Europe. CiA has still the largest communities in Germany, Switzerland, and Scandinavia.

Long cables: During plug-fest, CiA members stress their CANopen devices and proof the interoperability

Looking back, I have worked with several members very closely in the board of directors and in the CiA technical as well as CiA marketing groups. In general, I have to say that there was nearly always a friendly atmosphere even between competing companies.

Also in the CiA office, employees were coming and going. And some are working since many years for CiA, e.g. Thilo Schumann, the "senior" among the engineers, and Ute Eisenhoefer, who administrates the technical groups since many years. Since several years, CiA provides apprentices the possibility to become certified secretaries. This is our small contribution to qualify and to educate the next generation. Of course, we also offer young engineers ▷

CiA staff in Nuremberg (from left to right): Holger Zeltwanger, Oskar Kaplun, Gisela Scheib, Silvia Lößel, Ute Eisenhöfer, Julia Adolf, Reiner Zitzmann, Cindy Weißmüller, Mark Buchert, Birgit Rüdel, Christina Merling, Thilo Schumann, and Carlos Grünsteudel; Clementina Eisele and Olga Fischer are in parental leave

In memoriam to Ennit Hubert

Ennit Hubert, our web-master, passed away unexpectedly end of last year. She studied ethnology, African as well as German languages and literature. Since the year of 2000, she designed websites, in the beginning as freelancer and than she worked with Pulsar Interactive Media.
In April 2007, she joined CiA Office and designed the CiA website and layouted the CAN Newsletter as well as other CiA publications. She was also responsible for the production of the CiA product guides. We will miss her kindness and friendliness, an attitude that she had even in times of high workload. In the last months, she developed the prototype of the CAN Newsletter Online with huge enthusiasm.

Holger Zeltwanger

and other "newcomers" in our seminars the opportunity to learn something about CAN technologies. I have performed personally more than 1000 seminars and trainings in the last 20 years. This required a lot of traveling. Some of you may think: He has seen so many countries, he should be very happy. Actually, I have seen many hotels, conference centers, and airports. Okay, that's not all. I met many interesting and kind people, which I would not like to miss. Yes, I have many business partners all over the world, and some have even become friends.

On the other hand, I lost sometimes the contact to my family and friends at home, because of the many business trips (in some years more than four month). This is the price I paid.

Carol Li serves Chinese customers from her office in Guangzhou

The CAN users surprise me even today. There are so many new applications, which I never thought that they would use CAN technology: coffee machines, Pedelecs, sub-sea instruments, etc. Last year, I was surprised by the membership increase of about 50 companies. Perhaps this year, I will be surprised by the success of the CAN-FD protocol and its impact on the CANopen technology. I hope that also the success of the CAN Newsletter Online will surprise me. It is up to you, to surprise me furthermore.

If you would ask me, if I would do it again – to initiate the CiA and to manage this organization – my answer is: Yes!

CiA staff in Nuremberg and Guangzhou

Currently, the CiA office in Nuremberg employs 13 people including two apprentices. Five engineers are supporting CiA members in the development of specifications and recommendations. They also respond to technical questions coming in via email, fax, or telephone. In addition, CiA staff organizes conferences, seminars, stands on fairs. CiA's employees also publish magazines, product guides, and of course CiA's website. ◀

Table of contents

Energy efficiency

20 years CiA

Hardware

Engineering

Application

Software

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Publisher
CAN in Automation GmbH
Kontumazgarten 3
DE-90429 Nuremberg

headquarters@can-cia.org
www.can-cia.org

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

CEO Holger Zeltwanger
AG Nürnberg 24338

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Editor-in-chief
Holger Zeltwanger

Layout
Bettina Seuffert-Bischoff

Advertising Manager
Gisela Scheib

Distribution Manager
Julia Adolf

Electrified monorail system: Up to 1500 carts in different CAN segments

Franz Ott

Jürgen Wanner

Established 1966, Berghof comprises different departments. The automation and testing division has chosen CAN as a strategic network technology in the beginning of the 90ties. As founding CiA member, the company had used first the CAN Application Layer (CAL) protocol and migrated to CANopen a few years later.

"One of our first CAN customers was Fico (now BESI) manufacturing some semiconductor production machines," remembered Franz Ott, formerly head of the development and now managing the automation and testing division. "Other early CANtrol users were Gieseke & Devrient for chip-card personalizing equipment and SEG for gas, diesel, and wind-power systems (now Woodward)." In the 90ties, the company cooperated closely with Moog and PMA in the development of CAN products. One of the most important customers is Eisenmann using CAN-based control system for its electrified monorail systems (EMS). A new physical CAN layer has been developed by Berghof especially for these EMS applications. EMS are installed for example in the car-manufacturing plant. In the Ford factory in Cologne (Germany) the entire monorail system with embedded CAN communication has a length of 13 km comprising several segments. In each segment, up to 100 carts coordinate themselves via the CAN communication integrated in the monorail. The segments have a maximum length of 300 m. In total, up to 1500 vehicles populate the rail network. The carts transport the car components (e.g. doors, seats, gear, and engine) to the assembly workplaces. This is one of the largest CAN applications.

Other applications of the EMS include conveying of beer bottles and furnitures. Another system has been installed in the flower auction hall in Aalsmeer (Netherlands).

"We produce about 20000 modules, including- ▷

"25 mm was a challenge."

The modular CANtrol EC1000 PLC control system uses as an embedded backbone network Ethercat. The host controller module has just a width of 25 mm. "This was a real challenge," said Franz Ott from Berghof. The 400-MHz PowerPC runs the Codesys PLC software (version 2.3 or 3.4) and provides a CANopen interface supporting data-rates up to 1 Mbit/s. Local extension I/O modules are connected via the backbone network. The Ethercat backbone can communicate also to external devices, for example high-speed drives from third parties. The host controller provides an Ethernet interface for display units directly supported by the Codesys Visu software. The CANopen interface is also integrated into the PLC software.

PLC controllers, display-controllers and industrial PC's with CAN interfaces per year," said Jürgen Wanner from Berghof. He was already in the Esprit research project, which pre-developed the CANopen protocol. Most of the display-controllers are application-specific. "Machine builders are increasingly interested in these products, because they are less expensive than industrial PCs," stated Franz Ott. "We also have introduced recently the EC1000 controller (see info-box) featuring the Codesys PLC software compliant with IEC 61131-3." This DIN-rail mountable controller with an Ethercat backbone network provides CANopen connectivity for price-critical devices. "The first user is not using the Ethercat backbone, but the CANopen interface," said Ott. "The system will be installed in car garages, more details I can't give yet." This compact PLC system will complete the existing control units of the CANtrol product family. "But the CANopen interface will remain for connecting low-cost devices," promised Ott.

The CANtrol family of modular CANopen devices is also in duty in test and automatic calibration systems developed for automotive suppliers. One application example is the calibration of car seats for luxury class cars. The CAN-/LIN connectable seats embed weighing sensors, which needs to be calibrated end-of-line.

In operation of the car, the seats adjust airbag ignition depending on the weight of the passenger. This adjustment is performed by means of a complex communication. The AMS (audit measurement system) by Berghof also controlled by a CANopen-based system evaluates the different functions of car seats and records the results of the measurements. ◀

Company

Berghof GmbH
Harretstr. 1
72800 Eningen
(Germany)
controls@berghof.com

The company headquartered in Eningen (Germany) was a founding member of the CAN in Automation users' and manufacturers' group. Since mid of the 90ties, the company's automation and testing department with a branch office in Mühlhausen/Thuringia (Germany) provides in most of its products CAN interfaces, and will do it in the future, too. The 100-employees firm offers off-the-shelf control devices as well as application-specific control units optionally including application software.
In 2011, the automation and testing division achieved a turnover of about 18 million euro.

Links

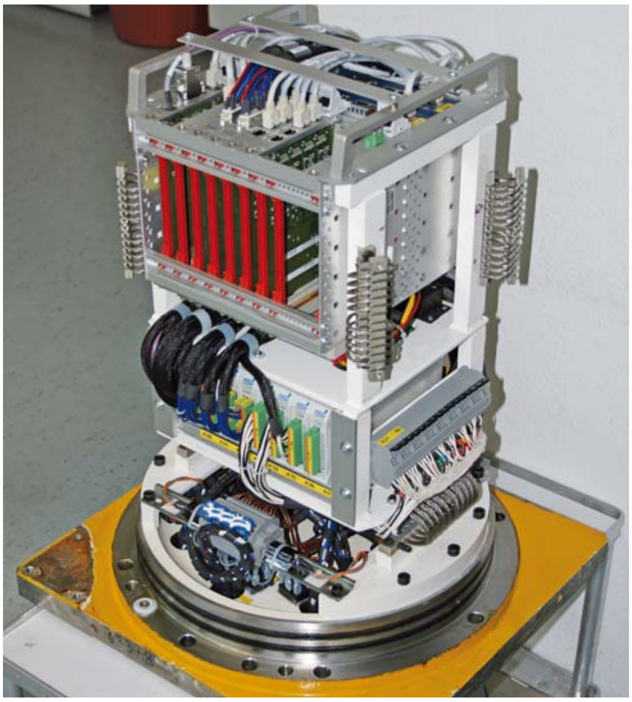
www.berghof.com
www.eisenmann.com

Not only partner of the medical device manufacturers

Klaus Detering

Harm-Peter Krause

Established originally as an engineering office, esd (electronic system design) has become a manufacturer of application-specific boards and computer systems. The company located in Hanover (Germany) offers also off-the-shelf products such as CAN interface modules, CAN gateways, etc. A sales office in Hamburg, a subsidiary in USA, and distributors in China and Korea as well as sales partners in France, Israel, Italy, and Japan support customers all over the world. Most of the business is done in Germany (about 60%), followed by other European markets and North America (each about 20%). There are also some interesting projects in Far East, e.g. wind energy systems in China using the CAN-to-Profibus gateway. Gateways are important products. In particular, the CAN-to-Profibus gateway provides some unique features: For example, configuration by the Simatic programmable logic controller (PLC) avoids additional configuration software and interfaces.



Controlling the hammering in sub-sea is a challenge: In the depth of 3000 m below the water surface the control system also needs to record all "hammering" data in order to proof the correct and sufficient process of fixing the piles into the ocean ground

"We are partner of all major medical device manufacturers," said Klaus Detering, CEO of esd. "They use our CAN products in nearly all image processing medical devices." The 60-employees company develops and produces since 1992 interface boards and modules for CAN. "Our first CAN interface product was an X-bus board," remembered Detering. "It was followed by the VMEbus CAN-2 board." Today, the company provides CAN interface modules for USB, and PCI and many other bus systems.

Besides the healthcare industry, esd provides for road construction machines IP65-rated control units featuring CAN connectivity. "Our CAN products are in ▷

CAN/USB module in the connector

The CAN-USB-Micro module by esd is powered via the USB interface. The local ARM Cortex M3 micro-controller and the CAN high-speed transceiver are completely enclosed in the 9-pin D-sub connector housing. On the USB side the module supports data-rates of 12 Mbit/s, and on the CAN side several bit-rates up to 1 Mbit/s are configurable. The USB dongle comes with the CANreal bus monitoring software and a Windows driver program (NTCAN-API). The USB cable has a length of 1,3 m.

about 70% of the road construction machines," said Detering proudly. Most of the sold CAN products are developed closely with the machine builder. These application-specific devices are used in broad range of applications. Recently, esd has redesigned the control system for a deep-sea hammer by Menck. It is now using embedded CAN communication between host controller and I/O modules. Another application is the test system in the Airbus production facility in Finkenwerder (Germany) testing equipment for cabin intercommunication and data systems of the A380 aircraft. The company has also equipped the test systems for the Flight Attendant Panel in the Airbus final assembly line. All the test modules feature CAN interfaces at the front-end as well as the backbone communication. In total, about 2000 modules have been installed in these test systems. The company also provides CAN interface boards with Arinc 825 protocol software to be used in the aircrafts.

"We produce per year about 35000 intelligent CAN interface boards and controllers," stated Harm-Peter Krause from esd. "About 60% are customer-specific." The company also offering Ethercat products doesn't manufacture the printed-circuit boards by itself, but the final testing is done in-house. "So we can guarantee 100% failure-free products," said Klaus Detering.

The company highly committed to the CAN technology, uses in about 50% its self-developed CANopen protocol stack. "For the future, we see besides the Ethernet hype, interesting developments for CAN in particular the upcoming CAN-FD protocol," explained esd's CEO. "CAN safety communication and CAN redundancy are other interesting topics for the future." ◀

Company
esd GmbH
Vahrenwalder Str. 207
30165 Hanover
(Germany)

The company, established by Klaus Detering and Dr. Werner Schulze in 1984, was a founding member of the CAN in Automation users' and manufacturers' group. In the 20 years history of CiA, esd's employees have been active in several technical groups as well as in the CiA Business Committee.

Link
www.esd.eu

Sub-sea hammer for the off-shore platform installation require very robust control systems

Recording in-vehicle data and maneuvers

Company
G.i.N. mbH
Raiffeisenstr. 15
64347 Griesheim
(Germany)

Wolfgang Bassenauer and Andreas Schoenberg, the CEOs of G.i.N. were founding members of the CAN in Automation (CiA) users' and manufacturers' group. In the meantime, the company has grown from two persons to 34 employees. Besides the headquarters in Griesheim, there is a subsidiary in Wolfsburg (Germany) close to Volkswagen, one of the main customers. Vector owns 48% of the company's shares.

Link
www.gin.de

1994 at Hanover Fair: W. Bassenauer (right) and A. Schoenberg (center) in discussion with H. Zeltwanger (left)

In 1991, Wolfgang Bassenauer and Andreas Schoenberg have established G.i.N. In the beginning, they produced the CanPC interface boards, the NetCheck hand-held tester, the *cmod* and the Tiny CAN module families. About *cmod* modules were installed in the Transrapid systems. Other customers are still using them.

"However, last year we have given the last *cmod* production documentation to our customer," explained the CEOs," so that they can manufacture the modules by themselves." One other of the first developments was the CANscope hardware and base software. This CAN physical layer tool, an oscilloscope with CAN protocol knowledge, has been enhanced several times and is still available from Vector. "The close cooperation with Vector avoided to establish own sales channels," said Wolfgang Bassenauer.

"Data-logger is our business – from simple to most sophisticated ones."
Wolfgang Bassenauer

In modern cars and vehicles, the development engineers need to record data, in order to prove the correct function of the communication and the application. "It is not sufficient just to log the in-vehicle network data," said Andreas Schoenberg. "The data streams from the up to 8 CAN networks, up to 8 LIN networks, the two Flexray networks and the Most network need to be directed and combined with application parameters requested via the communication links," added Wolfgang Bassenauer. The data-logger provides up to 36 independent gateway functions, which can be programmed in order to combine data from different networks.

The company has found a niche in the automotive industry. The company develops leading-edge data-loggers with challenging requirements: Short boot-up times, in order to wake-up the multiprocessor tool in less than 30 ms; and programmability of more than 100 trigger conditions for several recording scenarios including remotely demanded internal ECU data (diagnos- ▷

The GL3000/4000 data-loggers

The fundamental properties of these data-logger families include two ARM-9 processors: The real-time tasks (logger CPU) and the administrative tasks (Linux-CPU) are running parallel without interrupting each other. The time-critical CPU runs with no operating system overhead. This logger CPU is active immediately after wake-up regardless of the Linux start time. The ARM-7 processor cluster operates the communication interfaces. One micro-controller is able to manage up to four CAN networks and some additional interfaces (e.g. one LIN port and one K-line interface as well as an EIA 232 port or some LEDs). Besides the in-vehicle network data, the tools can capture several digital and analog signals in real-time. The data-logger supports several input and output formats including CANalyzer log file (LOG, BLF), ASCII trace (ASC) and MDF. The tools supports even 2D classification tasks with up to 25000 classes.

tics, CCP, XCP). The products are programmable on the system level, meaning that for example the brake data is recorded and pre-analyzed in dependence of engine temperature and speed. Some users define more than 250 recording tasks (classifications). The high-end multi-processor data-loggers, such as the the GL3000 and GL4000 series, are equipped with two ARM-9 processors and an ARM-7 micro-controller clusters. From the user's script C-programs are generated and downloaded into the micro-controllers' flash memories. The MultiLog series features one CPU.

In total, the company has sold more than 12000 data-loggers. These products are used for network analyzes, automated fleet operation, vehicle monitoring, and quality assurance, not only in the automotive industry. "Our products provide more than just data recording," explained Andreas Schoenberg. "For example, there is the voice-input capability as well as the camera, GPS, and tachograph inputs." The test driver can record also verbal information, which will be related to the automatically logged data.

"A short start-time and efficient programmability are the key-features."

Andreas Schoenberg

The company has already started to develop the next generation of sophisticated data-loggers. "We believe and know that the future cars will implement more CAN networks as today and of course Ethernet will play in the entertainment a more important role," said Wolfgang Bassenauer. "We are just in pre-development phase evaluating the demands of our customers." The data-loggers are like ECGs for highly networked embedded control systems. ◀

Radiation-resistant FPGA features CAN connectivity for mission-critical applications

Company
MEN GmbH
Neuwieder Str. 5-7
90411 Nuremberg
(Germany)
info@men.de

In 1982, Udo Fuchs, Manfred Schmitz, and Werner Witt established MEN. The company is one of the CiA founding members. Today, MEN employs about 230 people. The company is focused on mission-critical computer-systems and board-level products. They are mainly used in rail vehicle, airborne, and commercial vehicle applications. All printed circuit boards are produced and tested in Nuremberg, in order to achieve the requested quality. The company is IRIS, AS 9100, ISO 9001, and ISO 14000 certified. It runs daughter companies in France and in USA.

Link
www.men.de

Manfred Schmitz: "Most of our products provide CAN interfaces; CAN is for our customers like a UART."

MEN's oldest and largest CAN customer is the Oerlikon Textile group (with its brands Schlafhorst, Barmag and Saurer). Since 1993, the company produces the HMI-based host-controller hardware. The Schlafhorst machines are equipped with about 150 CAN nodes; the I/O modules are made by the machine builder. The 3000 controllers are produced by MEN. "We never make application software," said Manfred Schmitz, one of the two CEOs, "and we never install our products in machines and vehicles. This is the business of our customers."

The focus of the company has changed over the years: Nowadays, most of the systems and boards are used in mission-critical applications. An important group of customers are suppliers for and manufacturers of rail vehicles. This includes among others Ruf and Selectron in Switzerland, CAF in Spain, Alstom and Thales in France, Bombardier in Canada as well as Voith, Knorr-Bremse, and Siemens in Germany. In the future, MEN will supply safety-related equipment up to SIL 4 for automatic train control systems such as ETCS (European Train Control System) and PTC (Positive Train Control).

Another market addressed by the company is the airborne industry. One of the first customers was the Airbus enterprise. For the A-400M military transportation aircraft, MEN's engineers developed even an FPGA with a triple-redundant CAN module. The ▷

Modules for trains featuring CAN connectivity

For display and box computers

Designed for harsh environmental conditions in mobile markets, the SC24 single-board computer for display and box computer applications is equipped with the G-series processor by AMD. All interfaces are led to an extension card. "The modular design is qualified and tested by MEN to meet the operating temperatures of -40 to +85°C and prepared for e1 certification," said Aurelius Wosylus from AMD. The product is suitable for example for fleet management systems and for digital signage applications.

For space limited applications

Dedicated for railway, avionics, agricultural or construction machines or medical equipment, the ESMini MM2 COM (95 mm x 55 mm) is equipped with Intel's 1,6-GHz Atom E600 processor. It consumes 5 to 7 W. The module provides several interfaces including CAN, Ethernet, USB, and SATA. It comes with LVDS and SDVO for graphic applications. The product features a 2-GiB DDR2 SDRAM, which is soldered against shock and vibration. Different mass storage media can be accommodated directly on the carrier board. If the specified temperature range (-40°C to +85°C) is not sufficient, air-cooling can be applied on top of the conductive coolingcover, which encloses the module.

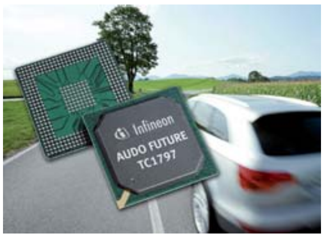
Respirator by Hamilton using an embedded CAN network

CAN implementation is able to detect and correct any single-failure. The FPGA is also radiation-resistant.

In medical and healthcare systems, several CAN-connectable controllers have been designed in. For example, B-Braun has equipped its infusion-pumps with such products, and Hamilton controls its respirators with CAN-linkable single-board computers and Computer-on-Modules. For industrial applications, the company provides a broad range of off-the-shelf boards with system integration service. However, more than 50% of the sold products are adapted to the customer needs or are entirely application-specific. Last year, the company sold about 60% of its electronics in Germany.

"We know all the standards and regulations for mission-critical applications," explained Manfred Schmitz. "We have specialized ourselves to railway, aircraft, and commercial vehicle industries." The automotive customers include ZF (Germany) designing fleet management equipment, Telemotive developing datalogger, one of the leading agriculture machine manufactuers producing Isobus-connectable agriculture vehicles, and Joy Mining manufacturing mining vehicles. In all of these applications CAN connectivity is required. "In many of our products we use FPGA with our own CAN implementation," said Manfred Schmitz. "In some applications, we implement CANopen as the higher-layer protocol, but most of our customers are using just CAN layer-2 software."

MEN supplies also products to the Phileas project running in the Netherland: The driverless bus uses redundant controllers with CAN connectivity. The system implements triple-redundant controllers, and is SIL-4 compliant. This means that one system consists of three single-board computers in a 2-out-of-3 configuration. Each is installed in a different place in the vehicle, so as to avoid a complete system failure in case of a collision. Every single computer obtains data from all sensors via two CAN connections and compares them with the other two computers' results. ◀



A brief history outline of Infineon's CAN modules

Ursula Kelling

Author
Ursula Kelling
ursula.kelling@infineon.com

Infineon technologies
Am Campeon 1-12
85579 Neubiberg
(Germany)

Link
www.infineon.com

During the last 20 years, Infineon has been producing different kinds of CAN micro-controllers. Even though, at that very time, still labeled with Siemens changing in the latest 90s to Infineon. Since then, many products have been designed and some of them are still in production. The most well known are the C505CA 8-bit micro-controller and the C167CR 16-bit micro-controller. Both do incorporate the original Bosch CAN module.

The CAN module of the C167CR incorporates 15 message objects, the last message object double buffered and the only one having an additional mask. All these 16-bit micro-controllers have only one CAN module, except the C167CS, which has two CAN modules. As time went by, it had been time for a new CAN module, so in the year of 2000 the TwinCAN was introduced. It was the very first big step giving the CAN module a more modern outline and giving it configurable FIFOs and a gateway function. The TwinCAN module still exists for example on the XC166 family.

The TwinCAN module already has flexible interrupts, interrupt sources and mask registers for every single message object. In many ways, TwinCAN provided many new features for applications, but very soon, more flexibility was needed so therefore Infineon introduced the MultiCAN module in 2003.

The MultiCAN module is the continuous development of the TwinCAN module and therefore includes almost all features, which have been introduced on the TwinCAN module. Starting with the TC1130, MultiCAN became the standard module on Infineon's micro-controllers and it is still today (e.g. on the Audo or the XC2000/XE166 families).

Up to eight CAN modules

MultiCAN is a scalable implementation supporting from two up to eight CAN modules. The number of message objects can be up to 256 message objects, shared for all nodes. The CAN implementation is compliant to ISO 11898-1 and supports the base and the extended frame format (11-bit and 29-bit identifiers). All modules support an individual analyzer function, which makes it possible to participate in the network as a passive member of the bus. Message objects can be connected to a FIFO or to a hardware-supported gateway. The message objects are no longer fixed, they are part of a linked list, so its predecessors and successors within the list can be programmed, meaning, that for example a FIFO can consist out of several message objects scattered over the message RAM. As already on TwinCAN, message objects are assigned to the individual CAN modules, if a customer needs 250 message objects on one node and two on another node and the rest with one each, this is fine. There are no additional circuitries needed or switching together nodes. The messages received are defined by the ▷

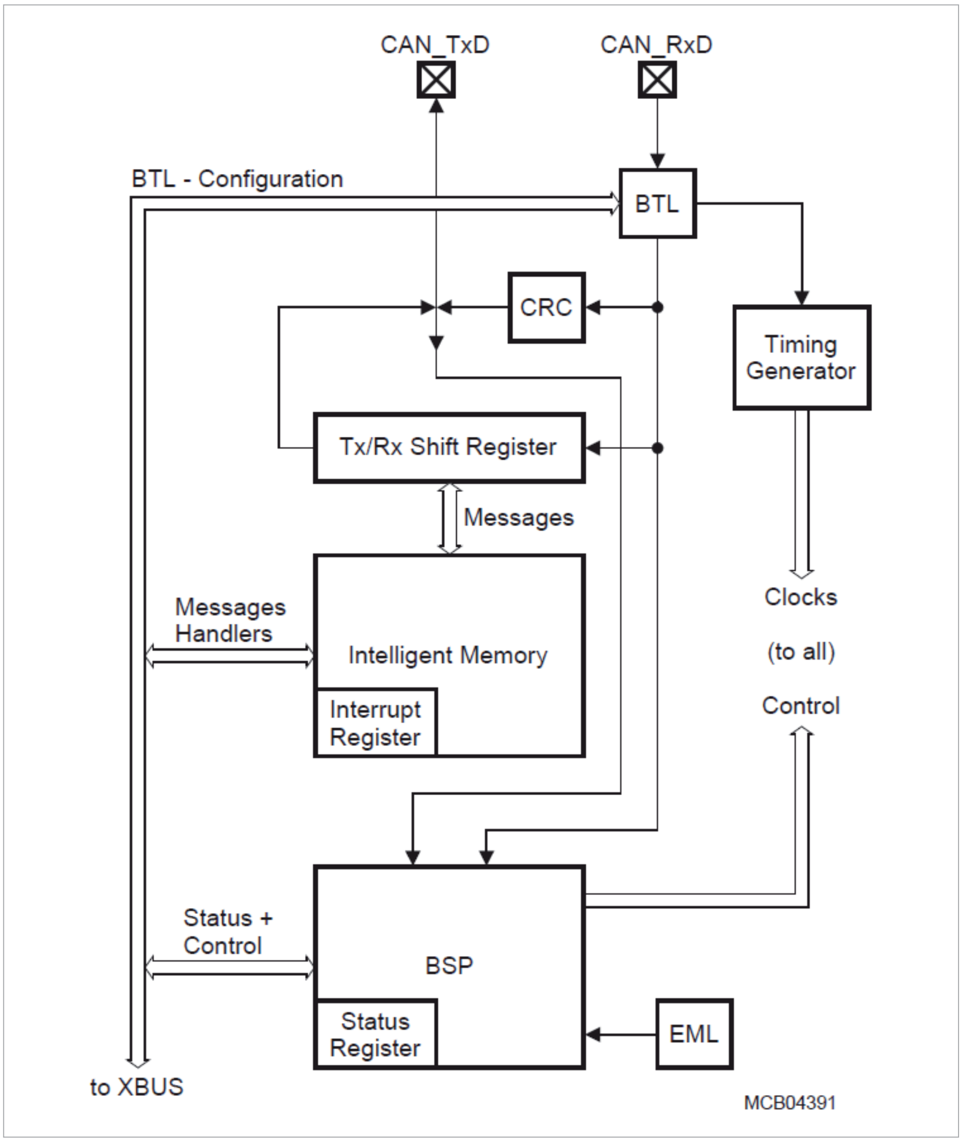


Figure 1: C167CR CAN module block diagram

identifier programmed into the arbitration register and its local mask.

The linked list controller as mentioned above is one unique benefit, as it gives the possibility to assign message objects freely to nodes and to link them together to FIFO or gateway structures.

A further benefit is the debugging feature, giving the possibility to detect, whether the resistor on the bus is the right termination. The measurement feature calculates the distance, between an outgoing edge and its runtime back over the receive pin.

To avoid errors and to ensure to use the right error-handling, MultiCAN offers a variety of mechanisms. In case the microcontroller implements two CAN modules, the following possibilities exist:

- Two CAN modules, two CAN transceivers, here two separate modules are connected over separate transceivers to one bus system.
  Plus: Transceiver errors are detectable.
  Minus: This concept needs two CAN transceivers
- Two CAN modules, one CAN transceiver, in this case two separate CAN modules are connected to one transceiver by having one receive connection.
  Plus: This concept needs one CAN transceiver.
  Minus: A transceiver error is not detectable.

Both concepts do have synchronized message access, which leads to the fact that short time disturbances are recognized by both CAN modules and lead to an error situation.

The CAN modules are handled asynchronously as the protocol handler is requesting the information one node after another. Message objects are appended to a node. If the application shall test, that a received message is really correct, for each node a message object has to be setup and compared via software. A disturbance on the bus is seen in different states and has a different impact. It is even possible to find a problem between protocol handler and message memory.

With upcoming safety applications and higher needs for checking an MCU, if it is working as expected, this feature becomes more and more important, as it is possible to check whether a message has been properly received.

Analyzer mode and other features

In the analyzer mode, the CAN module listens to the bus, but it is not actively taking part of the protocol. This feature is valuable for example in case the bit-rate shall be detected, without disturbing the bus.

Beside the analyzer mode, the MultiCAN module has additional features to prevent bus errors. It provides a synchronization analysis feature as well as driver-delay-measurement capability, which help to make further extensions of the bus safer and small disturbances on the bus less critical.

The synchronization analysis feature helps to prevent a possible bus error in case of slight changes or impacts on the bus. This function monitors the time between the first dominant edge and the sample-point measured and stored in a frame counter register. By using this function, it is easier to adjust the sample-point to the actual sample-point of the complete bus system.

The driver-delay-measurement helps to find a circuitry, where a sent edge is received time quanta before the sample point. Both features help to find a configuration and circuitry, which is not fault-prone to slide changes or disturbances on the bus.

FIFO and gateway function

FIFOs can be collected all over the message RAM and still forming a FIFO. The linked list control enables every message object to ▷

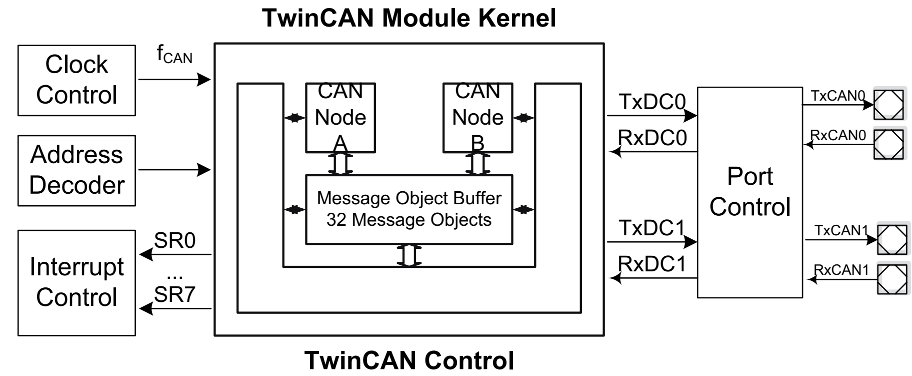


Figure 2: Block diagram of TwinCAN

Literature
Horst Müller: Integrated and stand-alone CAN solutions for different application levels (in: iCC proceedings 1994)

Robert Leindl: Complete CAN capability (in: iCC proceedings 1997)

Axel Wolf, Clemens Koller: 16-bit micro-controller with two on-chip CAN modules (in: iCC proceedings 1998)

Ursula Kelling: MultiCAN – A step to CAN and TTCAN (in: iCC proceedings 2003)

be assigned to a node dependent on the order within there the FIFO can be build by pointer mechanisms. The FIFO can be of any size.

On both implementations TwinCAN as well as MultiCAN, a gateway mechanism exists, enabling applications to reroute messages from one node to another not needing any CPU performance. Here by setting the corresponding pointers and bits, the message is copied to the destination bus and the transmit request is set automatically. The gateway function can be combined with the FIFO, so that even two busses running at different speeds can be interconnected.

MultiCAN has up to 16 interrupt nodes routable on different events (service request nodes). Each CAN module has four different interrupt events. Each message object can trigger an interrupt. The frame counters, available for frame or timing information has an overflow service request. The principle of the interrupt node pointer selection mechanism works by connecting interrupt events to an interrupt node. An interrupt can be connected to several events.

MultiCAN on industrial micro-controllers

Dependent on the micro-controller different outlines of the MultiCAN implementation exist. Coming from 6 CAN modules and 256 message objects on the XC2000/XE166 family down to 2 CAN modules and 32 message objects several configurations do exist. The 2-node configuration does exist for example on the XC800 devices as well as on XMC4500 devices. The XMC4500 comes also with an Ethernet module and a USB On-the-Go implementation.

To achieve easier interconnectivity the Ethernet module as well as the USB module has been coupled with a local RAM. The CAN module can transfer messages to and from this RAM via DMA, to enable a gateway function across USB, Ethernet, and the CAN modules.

The MultiCAN module will see some improvements to be ready for the next years. All improvements are done in such a way, that the "old" software will still be able to run on newer micro-controllers; simply the improvements can be switched on if needed. Improvements are done for example for pretended networking or for network management supervision. MultiCAN+ is ready for another decade with all the good things MultiCAN is offering and gets all the features to be ready for next years. ◀

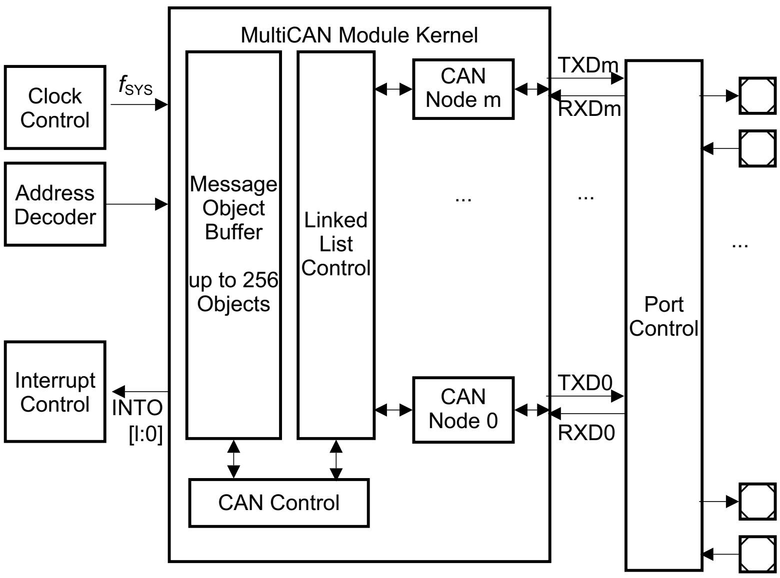


Figure 3: Overview of the MultiCAN Module

CANopen for small drives

Dr. Marcel Honegger

Author
Dr. Marcel Honegger
Project Leader
Mechatronics
Maxon Motor
Bruenigstrasse 220
Post office box 263
CH-6072 Sachseln
(Switzerland)

Links
www.maxonmotor.com
www.asyril.ch

With the continuing miniaturization of electronics and increase in the power density of electrical drives, many machines and devices can, today, be built much more compactly than they were a few years ago. And because fieldbuses such as CANopen are used, there is still very little cabling despite an increasing number of sensors and actuators. Even when there are significant price pressures on machinery, using a fieldbus can still be worthwhile. The CAN technology is known as a low-cost bus, not least thanks to the availability of a large number of micro-controllers and processors with integrated CAN controllers.

The use of the standardized CANopen protocol according to CiA 301 and device-specific profiles such as CiA 402 significantly reduces the development cost of the control software. Developers also have greater flexibility, as individual devcies can be exchanged without major changes. If, for example, a stepper-motor with relevant controller is replaced by a DC-motor with another manufacturer's controller, the machinery's control software hardly changes, as both drive systems appear almost the same on the CAN network when using CANopen profiles.

Just as the size of electrical drive systems and the costs are falling, so the requirements placed on performance and functional range are increasing all the time. And even for smaller devices, it is becoming increasingly important to synchronize individual drives with each other to realize more complex motion processes.

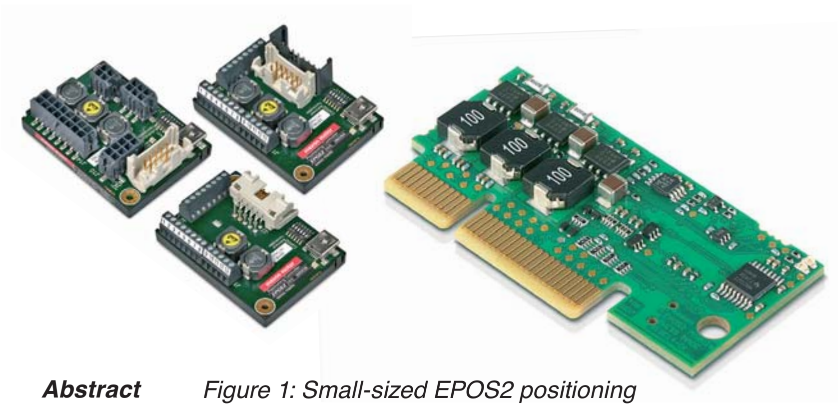


Figure 1: Small-sized EPOS2 positioning controller with CANopen interface

Abstract
Although designed as a fieldbus with line lengths of several meters, CAN networks today are widely accepted as an embedded communication system within compact machinery and devices. For applications, where space is limited Maxon Motor offers compact positioning controllers with CANopen interface. Apart from introducing compact CANopen-compatible positioning controllers, this article highlights various options on how the movements of several drives can be synchronized with CANopen. A miniaturized high-end robotic controller is referenced as an application example.

Control units for high-performance micro-drives

With EPOS2, Maxon Motor offers a family of universal positioning controllers for DC- and EC-motors with 1-W to 700-W nominal output. The EPOS2 24/2 controllers with up to 48-W nominal output were specifically developed for use in compact machinery, and the EPOS2 Module 36/2 with 72-W nominal output for OEMs (Figure 1).

The functional range of these controllers is largely identical to that of the larger EPOS2 drive controllers. EC-motors can be operated at up to 100000 rpm (rotation per minute), and due to a maximum of 2500000 encoder pulses, high-resolution encoders may be used while the encoder input frequency may be up to 5 MHz. Apart from CANopen according to CiA 402, communication interfaces offered by these EPOS2 controllers are also USB and RS232 as well as gateway functions of USB or RS232 to CAN.

These small controllers also support a wide range of operating modes, e.g. position, velocity or current mode. There are also functions such as "Step/Direction Mode" for the incrementally controlled movement of the motor shaft or "Master Encoder Mode" for applying the drive as electronic gearing. With the graphical user interface "EPOS Studio", these controllers can be efficiently parameterized and adjusted.

Synchronization of several drives via CANopen

For many multi-axis applications, it is sufficient for drives to move independently from each other. The drive controllers are typically operated in the "Profile Position Mode" or the "Profile Velocity Mode". In order to synchronize the movement of several drives, as required for multi-axis positioning systems, CANopen specifies several options. One preferred variant is the use of the "Interpolated Position Mode" (PVT, Position and Velocity versus Time). The host controller calculates the movement of all drives, periodically generates position and velocity support points, and writes these into the positioning ▷

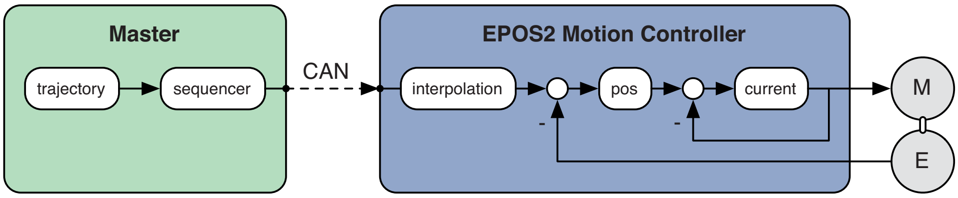


Figure 2: Periodically setting support points for the "Interpolated Position Mode"

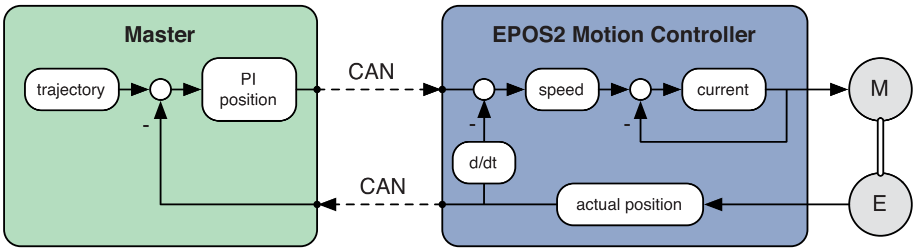


Figure 3: Control-loop closed via CAN with velocity set value by the host controller

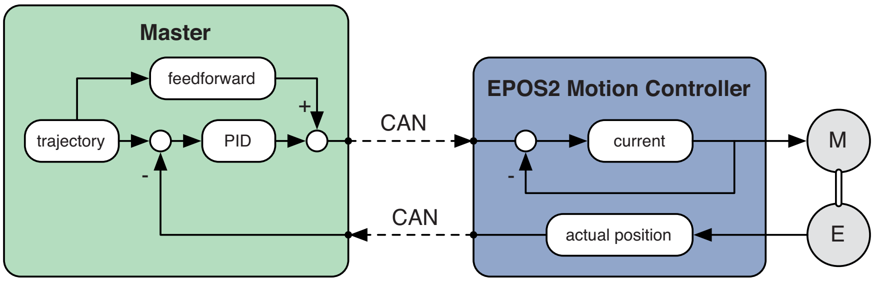


Figure 4: Control-loop closed via CAN with current/torque set value by the host controller

controller's message buffer. The motion controller in turn calculates set values for position control by linear or cubic interpolation. Positioning controllers' local timers can be synchronized on the CANopen network with the SYNC messages (Figure 2).

The periods between the support-points of the "Interpolated Position Mode" are typically between 10 ms and 100 ms, with the busload and real-time requirements on the host controller being low. However, one drawback of this operating mode is that motion cannot be changed very quickly.

If, for instance, motion is additionally synchronized with external sensors (vision, encoder from conveyor belt), this type of motion planning and control is too slow. Potential applications, where "Interpolated Position Mode" is useful are the automatic tracking of telescope and solar mirrors, or control of machine tools, where the movements of the axes are pre-determined.

Higher dynamics in motion planning can be achieved if motion planning and a part of drive control are carried out entirely in the CANopen master, e.g. with a position controller in the master and subordinate speed controllers in the drive controllers (Figure 3). The controllers are then operated in the "Profile Velocity Mode", but care must be taken to ensure that set values are applied immediately; otherwise the position control-loop cannot be closed. The EPOS2 positioning controllers also offer a true "Velocity Mode", which feeds velocity set values directly to the motion controller, leading to high control dynamics. The busload plus the requirements placed on the host controller's real-time capability are much higher with this control architecture, with cycle times of typically between 2 ms and 5 ms.

Another possibility involves realizing the position and velocity controllers in the master and setting the desired torque or current values in the drive controls via CANopen. To do this, CANopen specifies the "Profile Torque Mode". As an alternative, the EPOS2 controllers offer a "Current Mode" which directly feeds current set values to the current-controller via the CAN network (Figure 4). This leads to a high dynamic range, which is essential for coreless motors.

By directly commanding the current set value, more complex control algorithms can be implemented in the host controller, as required, for example, in robot systems with non-linear dynamics. Nevertheless, apart from sufficient processing power on the host controller, this architecture also needs hard real-time capability, as cycle-times should be around ≤1 ms. Such short cycle-times use up a great deal of the CAN bandwidth. Example: Sending a CAN message with a current set value and receiving a message with the actual position lasts almost 200 µs per drive at a transmission rate of 1 Mbit/s (see Table 1). A required cycle-time of 0,5 ms for only two drives on the CAN network already utilizes around 80% of the bandwidth.

Example: The PocketDelta robot

Asyril located in Villaz-St.-Pierre (Switzerland) has developed a micro-robot with delta kinematics for micro- ▷

Figure 5: asyril's PocketDelta robot

CANopen message	Data length	Duration at 1 Mbit/s
RPDO with current set value	2 byte	82 μs
RPDO with current set value, Controlword, Mode of Operation, digital outputs	7 byte	122 μs
TPDO with actual position	4 byte	98 μs
TPDO with actual position, Statusword, digital inputs	8 byte	130 μs
Heartbeat	1 byte	74 μs

Table 1: transmission times for different CAN messages

Conclusion
CANopen is suitable for use in compact machinery and apparatus, not least because it is inexpensive. With the EPOS2 24/2 and EPOS2 Module 36/2 positioning controllers, Maxon Motor provides CANopen-compatible drive solutions for confined spaces. Several drives can also be easily synchronized via the CAN network through support from various types of operating modes, including "Interpolated Position Mode". As the PocketDelta robot's controller shows, it is possible to realize highly challenging motion control applications using CANopen.

technology applications. With this kinematic structure a small platform with a gripper is moved in 3D space with parallelograms. Three motors drive the parallelograms (Figure 5). The robot's moving mass is therefore very low, making top acceleration and velocity possible.

The drives used are Maxon EC-i motors with 40-mm diameter and 50-W nominal output. With an internal, multi-pole rotor, these motors typically feature low-time constants, making them highly dynamic and giving them high-torque density. The EPOS2 Module 36/2 positioning controller drives these motors. This device is placed into the card slots of a motherboard developed specifically for small robots with up to four drives (Figure 6).

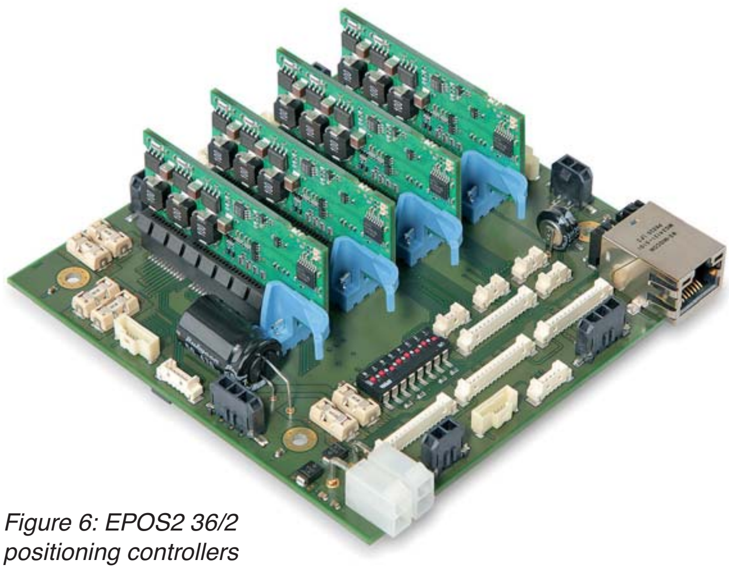


Figure 6: EPOS2 36/2 positioning controllers with motherboard

An ARM11 processor with on-chip CAN modules is used as host controller. This processor also sits on the motherboard and communicates with the EPOS2 via the CAN network. Other EPOS2 controllers, e.g. for feed systems or transfer axes, or even other CANopen devices, could be connected to the host controller providing NMT master functionality.

Highly dynamic robots such as the PocketDelta that can reach accelerations of 5 g and velocities of 2 m/s place high requirements on the drive controls. The dynamic equations of such systems are normally nonlinear and also coupled between individual drives. To reduce tracking errors to as few µm as possible at high acceleration and velocities, in addition to a specially designed feedback controller, a feed forward controller that calculates the entire robot's dynamic equations is applied.

The EPOS2 Module 36/2 controllers are operated in "Current Mode". In addition to motion planning, which must be synchronous for all drives, the host controller also calculates the control algorithms and the dynamic equations. The host controller then transmits the resulting current set values to EPOS2 via the CANopen network. The actual motor positions are captured with high-resolution encoders and sent to the host controller by PDOs from the EPOS2. This way, position and velocity control is closed through the CAN network (Figure 4). With an optimized definition of PDOs featuring as short a data length as possible and the various drive controllers divided onto two CAN networks, cycle-times of well under 1 ms can be achieved for control purposes.

In it from the beginning: Sensors with CANopen

Klaus Matzker

Author
Klaus Matzker
matzker@posital.de

Posital GmbH
Carlswerkstr. 13c
51063 Köln
(Germany)

Link
www.posital.eu

Introduction

As early as 1996, the German manufacturer Fraba Posital launched an absolute rotary encoder with a CANopen interface. Working with other manufacturers in the CiA special interest group (SIG) for encoders, Posital submitted its encoder profile proposal. The atmosphere among the working group members and within CiA as a whole was so very open and constructive that many parts functions were included in the CiA 406 profile. The final vote was conducted only a few months after the first meeting. Following this success, several parts of the existing CANopen encoder device profile were adopted for DeviceNet a few years later. This was a big advantage saving much effort because it made re-definition and re-implementation unnecessary. Furthermore, the end user gets the same "look and feel" on the device and application sides.

After the first launch of an encoder with a CANopen interface, Posital optimized its products continuously. The first and most pressing concern was price reduction since fieldbus interfaces used to be more expensive than standard interfaces such as SSI or Bit-Parallel. The situation in those early days can be compared to the disparity between fieldbus and Ethernet interfaces as it is today. Very quickly, we offered CAN products at the price of standard interfaces. Presented with such a choice, customers naturally preferred the more robust and flexible CAN network. Very recently, we developed a design for real-time Ethernet systems like Powerlink or Ethercat at costs similar to those for standard CAN interfaces. These systems use many parts of CANopen such as the device and communication profile.

Especially in the first years, customer support was one of our main fields of activity with the fieldbus experts providing help regarding installation, configuration, and diagnosis. Around the year 2000, fieldbuses became more and more popular and the sales volume of CAN connectable encoders increased dramatically. Not only did the number of sensors amplify, the manufacturer also reached a much larger variety of automation applications, for instance cranes, packaging, bottling, robotics, presses, transport, and feeding machines.

Figure 1: The Optocode CA series of optical absolute encoders with CANopen connectivity

New markets and applications

Our next major CAN development was the integration of the encoder profile in the application profile for the lift industry about ten years ago. This development opened up a vital market. Today, many of the company's customers use its CAN encoders in their lift installations. However, our efforts over the last 15 years were not limited to improving the CAN communication side. In addition to the optical measurement principle, the company adopted a new technology and extended its product range to magnetic systems. This enabled us to provide practical solutions for many more applications including mobile or construction machines. These application segments require particularly high ingress protection degrees up to IP69K, high shaft loads up to 300 N, immunity against shock and vibrations, and a wide temperature range. In addition to that, they are very cost-sensitive. It is noteworthy that CAN was first introduced in the automotive industry and, several years later, was adopted by manufacturers of heavy machinery such as rock drilling machines, mobile cranes, drilling rigs, or pile hammers.

Heavy-duty magnetic encoders

We supply heavy-duty magnetic encoders as a stainless steel model and as a compact, cost-efficient version. Both feature a hardened shaft, providing an optimal contact surface for the shaft seal even at highly dynamic speeds.

This constructive feature ensures IP69K protection on the shaft side throughout the long lifetime of the encoder. The housing, including the connector, is also designed to continuously withstand high-pressure water jets. The sensors are therefore suitable for worldwide use, in remote areas, and under extreme ▷

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Company

Posital is specialized in absolute rotary encoders and inclinometers. The company belongs to the Fraba group, which dates back to 1918, when its predecessor Franz Baumgartner elektrische Apparate GmbH, a producer of relays, was established. Today, the group consists of six independent companies that develop and produce industrial sensor technology and safety equipment.

Product information

Posital manufactures the Optocode line of optical absolute encoders with CANopen interfaces. With a housing measuring 71 mm in length, the encoders are suitable for use in applications with limited installation space. Standard models are equipped with a proven connection cap, which allows for user-friendly configuration by means of a switchable terminating resistor, an integrated T-coupler, diagnosis LEDs and BCD switches for manual adjustment of the bit-rate. Encoders from the Optocode CA series are available with a plug connector or a cable exit. These connection types are especially suited for price-sensitive markets. In addition to the established solid-shaft or blind hollow-shaft models, CA encoders are also available as easy-to-integrate through hollow shaft versions. Like all encoders, the CA models use a tried and tested optoelectronic scanning method to record position values. The single-turn part provides a resolution of 16 bit per revolution. Multi-turn units register a maximum of 16384 revolutions (14 bit), thereby covering an overall 30-bit measuring range.

Figure 2: Graded versions of MCD magnetic encoders for heavy duty

Figure 3: Cost-efficient, robust ACS II inclinometers

environmental conditions. Industrial applications of the high-end model range from the food industry to offshore applications. The compact sister models can be used in various automation applications and in mobile machines. The variants are suitable for high radial and axial shaft loads of up to 200 N and 300 N respectively.

Inclinometer

As a second portfolio segment apart from encoders, we started developing inclinometers. The CAN interface, tested and proven in the encoder design, was retained and extended by two versions of inclination measurement sensor cells. To meet the specific requirements of a wide variety of applications, e.g. high resolution, short response time, immunity against shock or vibrations, we employ both, MEMS (micro-electromechanical systems) technology and the fluid-cell measurement principle.

The Acclens series of IP69K inclinometer is based on MEMS technology and ensures shock resistance up to 100 g and vibration resistance up to 10 g. Since ACS II inclinometers measure inclination values directly, the ultra-compact devices require no mechanical coupling to drive elements, thus generating substantial savings for users. Moreover, a single sensor measuring several axes minimizes the constructive effort compared with other solutions, e.g. by making mounting fixtures and couplings unnecessary. A simple, very robust design allows users to realize cost-efficient sensor solutions for mobile machines. In addition to a CANopen interface, we also offer models with an analog, SSI, or EIA 232 connection.

Safety encoder

A recent highlight in the CAN product family was the development of an optical SIL CL 3 encoder with a CANopen-Safety interface, which was certified by the German testing authority TÜV Rhineland in 2009. Especially in light of the obligations on machine builders by the Machinery Directive, it is advisable to use certified devices which do not require engineering effort, thereby minimizing costs and implementation times. In contrast, standard components often do not cover common cause failures (CCF), forcing users to take special measures, which further increase their costs.

The redundant OCD encoders fulfill the requirements of IEC 61508, EN 62061 (SIL CL 3) and EN ISO 13849 (performance level e) and thus comply with the Machinery Directive. Operated with protective extra low voltage (PELV), they are suitable for use in drive systems, lift applications, mobile machines, construction machinery, and machine tools. The safety encoders support the CANopen-Safety protocol according to EN 50325-5 as well as the CiA 301 CANopen application layer. The single-turn sensors provide a maximum resolution of 16 bit per revolution. Additionally, up to 16384 revolutions (14 bit) can be registered in multi-turn mode, thereby cover- ▷

Figure 4: OCD encoders with redundant design for safety applications

ing a measuring range of up to 30 bit. The encoders are available as solid-shaft, hollow-shaft or synchronous shaft models. They provide IP65 protection on the housing side and IP64 on the shaft side (an optional sealing ensures IP66).

Draw-wire sensors

The Magnetcode draw-wire encoders are designed for medical applications. They use a hall sensor for single-turn, or the Wiegand effect for revolution measurement. They are available as MDW versions with an integrated draw-wire adapter, which makes them ideally suited for medical applications, e.g. in patient positioning and to control or monitor CT scanners or other imaging systems. The compact system provides magnetic, touch-free distance measurement at a 35-μm resolution. The maximum measurement length of 2 m is sufficient for medical applications. The units feature a serial SSI interface for connection to control systems. Originally developed for industrial applications, the units are especially wear-resistant: stress tests have shown that the absolute accuracy of the distance measurement systems remains the same even after the draw wire has been extended one million times.

Figure 5: Long-life Magnetcode draw-wire encoders for use in medical technology featuring precise distance measurement

Conclusion

Posital has been integrating CAN interfaces into absolute encoders since the mid-1990s. The company's expertise in bus interfaces has had a major part in the market success of its encoders. Over the last decade or so, opto-electronic scanning has been complemented by magnetic encoder technology, and the product portfolio has grown to include inclinometers and draw wire sensors. Today, the manufacturer supplies suitable models for virtually all possible applications. In the future, Posital will keep on developing dedicated solutions for new applications and as a member of CiA continue its networking and standardization efforts.

The One-Box concept of the British Police

Abstract

The One Box Concept is much more than just technology; it is a criteria (Standard), owned by CAST, which aims to standardize the architecture, fitment and functionality of all additional equipment fitted to police vehicles, to provide a technology platform, on which existing and future systems can operate. The team has additionally developed a new approach to managing emergency services vehicles and drivers, the DVDMS. This replaces the current incident/journey data recorders, to better manage both police drivers and vehicles, improving safety and driving down costs.

The "One Box" Single Vehicle Architecture (SVA) is transferable across all the emergency services but also into any vehicles that contain additional technology, beyond that fitted by the manufacturer. It should be stated from the outset that "One Box" is a concept name only and does not intend that all the functionality is fitted into one box. The key to the project is in the integration of technology into and connecting with the architecture of police vehicles of today and into the future.

The project began in 2008 and consists of two phases of work, Phase one (Single Vehicle Architecture) and Phase two (Driver and Vehicle Data Management System).

Phase 1 - The Single Vehicle Architecture (SVA) criteria

The SVA is a criteria set and owned by CAST and describes a standardized technology platform or architecture for the equipment fitted to emergency service vehicles, which has been designed to work and integrate with the equipment installed by the vehicle manufacturers.

The SVA provides a standardized specification for all vehicle manufacturers and suppliers to adhere to. This is an enabler to a true "plug and play" solution for all emergency equipment fitted to vehicles, thereby reducing the time required to equip and decommission vehicles, whilst at the same time increasing reliability and reducing cost through the reduction of wiring complexity.

The main areas that the SVA specifies include:

- Power management
- Cabling
- Controls and switches
- Wired LAN for data transfer around and off the vehicle
- Human machine interface (HMI)

The introduction of the Emergency Services Controller Area Network (esCAN), which links directly to the vehicles own CAN systems (with support from the vehicle manufacturers), maintains functionality and allows for seamless integration of future technology.

Having developed the architecture, ACPO ITS were struggling to find a common CAN code to develop a data dictionary that could be used to allow the transfer of data between the vehicle CAN systems and the newly developed esCAN, to allow the functionality detailed below. They had even considered writing their own data dictionary.

At this point, CiA was able to assist. Having had initial discussions with Vauxhall/Opel and had CiA 447 identified as a potential option, a telephone conversation took place, where it became clear that CiA 447 would meet the vast majority of the ACPO team's needs. As a result, ACPO then joined CiA and a meeting took place in Nuremberg to discuss further areas of commonality and highlight areas where the ACPO team required assistance from CiA to develop new code to meet the UK requirements.

Following assistance from CiA, a data dictionary has been developed for the police service, to allow the transfer of data between the esCAN and in-vehicle networks and allow interoperability between the vehicle and after market emergency service systems. In addition, it has also allowed vehicle manufacturers, across the EU, most of whom are members of CiA, to recognize and work with this CAN standard in the development of standardized police vehicles.

The importance of the HMI between the driver and the vehicle's additional equipment, in line with the EU guiding Principles of HMI was also recognized by the team and has led to the integration of equipment, ensuring the driver is able to work in the vehicle in the safest and least distracting environment. It also includes a common panel of five of the most safety critical emergency equipment switches, which are operated via the esCAN. These switches are fitted in the same general area and in the same order in every vehicle and were agreed with the users, to ensure commonality across vehicle types and forces in the UK. One vehicle manufacturer has suggested that savings of £250 to £600 per vehicle across the vehicle life are achievable by fitting SVA.

At the recent HOSDB Exhibition in March 2011, Vauxhall demonstrated an ▷

Insignia, the first SVA-compliant vehicle to be produced by a manufacturer in the UK. ACPO ITS are continuing to work with other vehicle manufacturers to assist them achieve SVA compliance.

A recent meeting in Paris has generated significant interest within the French Police, who are keen to adopt SVA for their vehicles. The ACPO ITS team is working closely with the French Interior Ministry to assist implementation and have met with police counterparts in Germany.

Phase 2 – Driver and Vehicle Data Management System (DVDMS) criteria

The second part of the project focuses on the development of a DVDMS system that is able to manage both vehicles and drivers by comparing driving behavior against specific profiles, utilizing CAN data from the vehicle and esCAN, via a CiA 447 conversion protocol, then turning it into easily understood information via a back office system. This information is tailored to the needs of each respective user for example driver, police supervisor, fleet manager, to both improve driving standards, reduce costs and manage the vehicle fleet in a more efficient way.

The development of the data dictionary, using CiA 447 is crucial to the development of these systems, allowing proprietary vehicle manufacturer code to be translated, via an interface into CiA 447, thereby protecting the proprietary information of the OEM.

Field trials of these systems are due to take place in a number of Forces across the UK in summer of 2011, with results of the trials being reported in early 2012. Early indications suggest that there are potentially significant savings to be made across the UK police service. ◀

The team

The Association of Chief Police Officers Intelligent Transportation Systems (ACPO ITS) working group, supported by Home Office – Centre for Applied Science and Technology (CAST), has led a public private partnership, including the Police Federation of England & Wales, OEM's and third party suppliers to develop the "One Box" Single Vehicle Architecture (SVA) and Driver and Vehicle Data Management System (DVDMS) concept and functional requirements.
The ACPO ITS working group is a research organization in the UK, established under the Association of Chief Police Officers (ACPO) Roads Policing Business Area. The team currently consists of five full-time police officers; who are seconded to the team to undertake research and development projects on behalf of the police and emergency services, both in the UK and across Europe.
The ACPO ITS working group are committed to making police vehicles a safer place to work, assisting in the cost effective measures that need to be implemented across the UK, working with European colleagues and supporting all police employees through technological advances to achieve the maximum performance possible.

Haircut with a hot flame

Bernd Wieners

Author
Bernd Wieners
Key Account Manager
Automation
Lenze SE
Hans-Lenze-Str. 1
31855 Aerzen (Germany)

Links
www.lenze.com
www.osthoff-senge.com

Singeing machines
Little hairs or threads sticking out of lengths of fabric impair processing of the cloth and reduce the quality of the end product. If the surface of a textile is not free of fibers and is then printed on, for example, the printed pattern or image looks blurred and dirt adheres to the surface more easily. All over the world, fabrics are therefore being pre-processed with singeing machines and pre-treatment equipment from Osthoff-Senge GmbH. A coordinated, uniformly designed automation system from Lenze ensures a high degree of precision, unimpeded operation of the machines and easy operator control. It is characterized by flexibility and an excellent price/performance ratio.

Figure 1: Textile finishing line with singeing station by Osthoff-Senge

More than 3000 singeing and pre-treatment lines of Osthoff-Senge, a company located in Wuppertal (Germany), are being used all over the world in order to remove fibers protruding from woven materials, knitted fabrics or technical textiles such as glass fibers or fleece. The extremely smooth surface that is achieved in this way not only makes the fabric appear fine and clearly structured but also facilitates further processing and cleaning. This is because the tendency to become dirty and the pilling effect are reduced.

The principle of singeing (also called gassing in technical jargon) has been the same for centuries and is actually quite simple; the fabric to be treated is taken past an open gas flame at high speed, whereby the protruding fibers and fluff are burned off. In order to achieve high-quality singeing results, the flame intensity and the machine speed during the singeing process must be optimally matched to the material to be processed. Also it must be possible to adjust the flame intensity appropriately during singeing. Moreover, the singeing flame must be as homogeneous as possible across the entire width of the web.

These requirements are what the machines and equipment of Osthoff-Senge GmbH are renowned for worldwide. The burner technology developed by Osthoff-Senge and protected by patent produces a flame with a heat of 1250°C. This makes it possible to remove protruding hairs and other excess material from natural, regenerated and synthetic fibers in fractions of a second. Usually, singeing is preceded by a cleaning stage and followed by further processing to remove ash residue and dirt. Other finishing procedures such as de-sizing, impregnating or cold-bleaching can also be ideally combined with singeing.

Universal control program

When it was decided to develop a new control platform, the declared objective of the team responsible was therefore to combine the different machinery and equipment in only one single control platform and thus save time and money.

"In concrete terms, this meant that we only wanted to create one control program and one system for visualisation and operator control of the machines. It also had to be possible to configure this program and system in order to adapt them to equipment in the field and to equipment that would be supplied in the future", said Heiko Wilke when explaining the situation. "The obvious thing to do was to consider Lenze as a possible supplier as we had already had good experience with Lenze's drive technology and service. Moreover, the company was now offering complete automation systems."

In an internal evaluation at Osthoff-Senge, Lenze came top against ten ▷

Figure 2: As a hardware platform, Osthoff-Senge uses Industrial-PCs from Lenze

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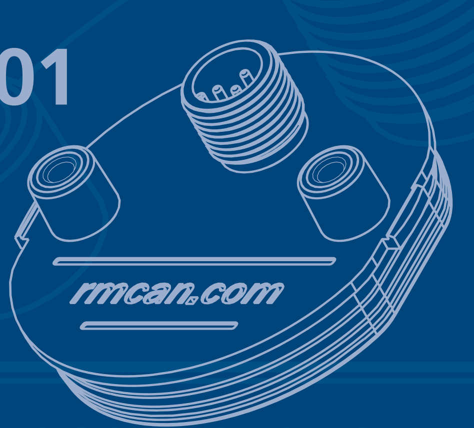

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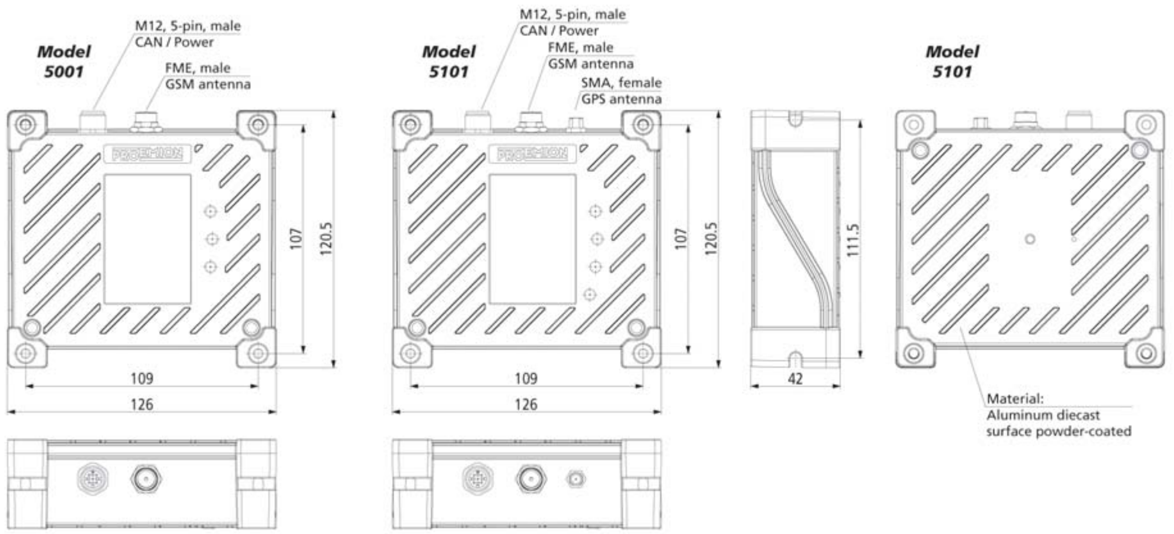

Mechanical Data	5001	5101
Dimensions width / height / depth [mm]	126 / 120.5 / 42	
Degree of protection	IP 65	
Temperature range	–30 °C … +75 °C / –22 °F … +167 °F	
Weight	650 g	
Electrical Data		
DC power supply	6 V – 32 V	
Power input @ 24 V	ø 210 mA / max. 600 mA	
Memory: Program / Configuration / Data	384 kB / 4 MB / 512 kB	
Status LEDs (2 colors)	3	4
Interfaces / Protocols		
CAN	1 (ISO 11898-2 high speed, 2.0 A/B)	
GSM / GPRS / SMS quad band	850 / 900 / 1800 / 1900 MHz (class 10)	
GPS (tracking capability)	-	22 channels
GPS (accuracy)	-	3 m
CANopen®, Layer 2, J1939	✓	
CAN Kingdom, DeviceNet, customized	on request	
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Headquarters
Donaustr. 14, 36043 Fulda, Germany
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info@rmcan.com, rmcan.com

PROEMION GMBH

Headquarters
Donaustr. 14, 36043 Fulda, Germany
Phone: +49 661 9490-600, Fax: -666
info@proemion.com, proemion.com

RM MICHAELIDES
SOFTWARE & ELECTRONIC CORP.
US Subsidiary
711 E. Monument Ave., Suite 310
Dayton, Ohio 45402-1490, USA
Toll-Free US: +1 877 RMCAN-US
Phone: +1 937 558 2211
Fax: +1 937 641 8787
info@rmcan.com, rmcan.com

PROEMION CORP.

US Subsidiary
711 E. Monument Ave., Suite 310
Dayton, Ohio 45402-1490, USA
Toll-Free US: +1 877 RMCAN-US
Phone: +1 937 558 2211
Fax: +1 937 641 8787
info@proemion.com, proemion.com

Figure 3: Osthoff-Senge is planning to change over to the 8400 inverter platform with integrated CAN interfaces

Figure 4: The VisiWinNET environment provides an intuitive user-interface

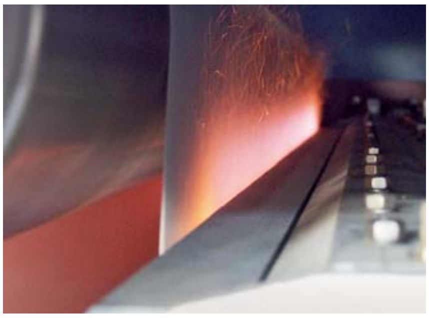


Figure 5: During singeing, very fine hairs and threads are removed from the fabric's surface

other suppliers. An external check by a recognized engineering-services provider, which examined the technical aspects in detail as well as the prices, arrived at the same conclusion.

Since then, Osthoff-Senge has used devices from Lenze's Embedded Line family of PCs as a hardware platform for its 'Seng-Matic' control and monitoring system, which automatically adjusts, monitors and controls all parameters that influence the singeing effect. A soft-PLC L-force Logic, which is programmed in the engineering environment 'PLC Designer', runs on the platform. "Because PLC Designer is based on Codesys and therefore has practically no memory limits, we were able to incorporate every conceivable feature of the equipment into the universal control program. On each individual item of equipment, only those parts of the program that are actually needed are then used", explained Heiko Wilke. "On top of this, having Lenze as the supplier means that we do not have to immediately change over to a more expensive device with more computing power or to a completely different platform merely because an application needs more memory. This would not be the case if other suppliers had been used."

Wilke was also very positive about the openness of the system: "Codesys possesses interfaces that we have used to implement our own functions and also to automatically generate codes from Excel lists without having to do such complicated work manually."

The head of development also appreciates the great flexibility of VisiWinNET, the visualization system by Lenze: "The development environment has been completely integrated into Microsoft Visual Studio. Visualization and operator-control applications can thus be implemented in such as way as to satisfy all possible needs." In this way, according Wilke, Lenze has created an intuitive user-interface. It allows the machine operator to open windows by a mouse-click within a visual representation of the entire installation. Each window then shows a detailed view of the selected part of the installation and enables it to be controlled by the operator.

The axes of the machinery, of which there are five up to a maximum of ten, are controlled by inverters from the 8200 vector and 9300 vector families of drives. For cost reasons, these inverters are connected to the overall control system not by means of a bus but via digital inputs and outputs. The machine builder uses the modular IP20 I/O system and thus has consistent automation from the inverter through to visualization. ◀

Figure 6: In future, Osthoff-Senge intends to use the IP20-rated I/O system

No installation is the same as another

"Because many possible pre-treatment processes exist in addition to singeing, there are hardly any two installations that are completely identical", explained Heiko Wilke, head of development at Osthoff-Senge GmbH. "The scope of requirements that we have to place on the control system is therefore correspondingly large. In the past for reasons of cost and performance, we were only able to cover these requirements with several control platforms. This entailed additional expenditure and time in respect of hardware and software engineering, also maintenance."

A look into the future

"Due to good experience with Lenze's drive technology, we had already built up a great deal of trust in this supplier when it became necessary to modernize our 'Seng-Matic' control and monitoring system", summarized Heiko Wilke. The company also plans the replacement of the current modular IP20 system by the new I/O System 1000 from Lenze. On the drive side, Osthoff-Senge intends to change over to the latest products; the 8200 and 9300 vector inverters will then be replaced with the 8400 inverter family. "The CAN interface already integrated as a standard feature of these drives will enable us to switch over to bus technology for integration of the inverters, in spite of the high cost pressure in our branch of industry", concluded Heiko Wilke looking at the near future.

Vacuum pumps using frequency inverter

Elmar Lohkampff and Christine Reiff

Author
Elmar Lohkampff
Key Account Manager
Yaskawa Europe GmbH
Hauptstr. 185
65760 Eschborn

Ellen-Christine Reif
Editorial office Stutensee

Links
www.yaskawa.eu.com
www.oerlikon.com

The conception and implementation of a new generation of pumps within a short design period is a technical challenge even for experts that are experienced and competent in the design and production of vacuum pumps. This is particularly true if product innovations need to be implemented that cannot be covered by in-house core competences. It is not uncommon to seek reliable external partners that can offer the corresponding know-how, and this is also what happened for the new, dry compressing helical vacuum pump.

Figure 1: The V1000 frequency inverter series are being used in vacuum pumps and are fine-tuned for the application with additional functions

All pumps of the Dryvac series are equipped with state-of-the-art frequency inverters made by Yaskawa that proved to be highly robust and reliable in comprehensive tests during the new pump generation's design phase. Moreover, Yaskawa was able to offer good, trustworthy support during the entire design process. Oerlikon Leybold Vacuum also appreciates that all product-specific requirements for the frequency inverters had been taken seriously and been implemented as desired. What's more, the supplier also met one of the key deciding criteria: a good price-performance ratio.

The pumps with integrated frequency inverters (figure 2) offer a number of advantages. The user is not required to purchase a separate inverter and to mount and wire it in an electrical cabinet. Due to an optimum match between motor and inverter, this also ensures energy-efficient operation, which not only meets statutory requirements but also lowers operating costs. Inverter integration offers flexibility for machine builders and ensures their independence because these pumps can be deployed worldwide under a wide range of mains voltages and frequencies.

Dry compressing helical pumps

Oerlikon Leypold Vaccum's highly diversified product offering comprises pre-vacuum and high vacuum pumps as well as complete vacuum systems including matching accessories plus service and maintenance for vacuum technology. The Dryvac series vacuum pumps serve as a good example. These dry compressing helical pumps have specifically been designed for the high process requirements of the photovoltaic industry as well as for a number of surface coating technologies, and are suitable for very demanding applications. When designing the pump generation, designers had been focusing specifically on the implementation of a wide variety of today's user requirements. After all, optimized vacuum technology as part of the process does not only improve productivity, but also boosts efficiency and minimizes the use and consumption of further resources. This requires meeting statutory provisions for energy efficiency, but also has to allow for current trends to implement measurement, control and monitoring of individual subsystems such as of a vacuum pump stage using bus systems such as CANopen.

These vacuum pumps have been specifically designed for the process requirements in the photovoltaic industry as well as for a number of surface coating technologies.

Abstract
Vacuum technology forms the base of many industrial production processes. The various types of vacuum are divided up into the areas of raw, fine, high and ultrahigh vacuum. Vacuum technology is being used not only in the process industry and surface coating but also in research and development. Vacuum pumps therefore are being deployed in a wide range of applications. These range from metallurgy and furnace construction via freeze-drying and crystal pulling up to surface coating technology for the production of DVDs, photovoltaic panels and displays. Further applications can also be found in mass spectrometers, electron microscopes or gas analysis equipment. Users in these areas expect performance and reliability of new products, but above all energy efficiency, communication functions and convenient control and monitoring capabilities. Modern frequency inverters can contribute considerably to meeting these criteria, as can be seen in the description of the application below.configuration. The devices featuring analog and digital I/Os are hot-pluggable.

Oerlikon Leybold Vacuum

The company headquartered in Cologne (Germany) is offering modern solutions for vacuum technology that can be used in production and analysis processes as well as in research and development. The company's product offering includes pre-vacuum pumps, high and ultrahigh vacuum pumps, vacuum systems, vacuum measurement instruments, leakage detectors, components and valves as well as consulting and engineering for comprehensive vacuum solutions for custom applications.

Yaskawa

The Japanese company provides world-wide servo drives, frequency inverters and industrial robots. The company's products are used in many industrial markets such as automobile production, packaging, wood processing, semiconductor and pump technology as well as elevator and escalator technology. Yaskawa claims to be the world's largest manufacturer of AC converters, servo-motors, direct drives, machine controls and robots. The company is currently producing more than 1,700,000 frequency inverters, over 800,000 servo systems and in excess of 20,000 industrial robots per year.

Integrated ancillary functions

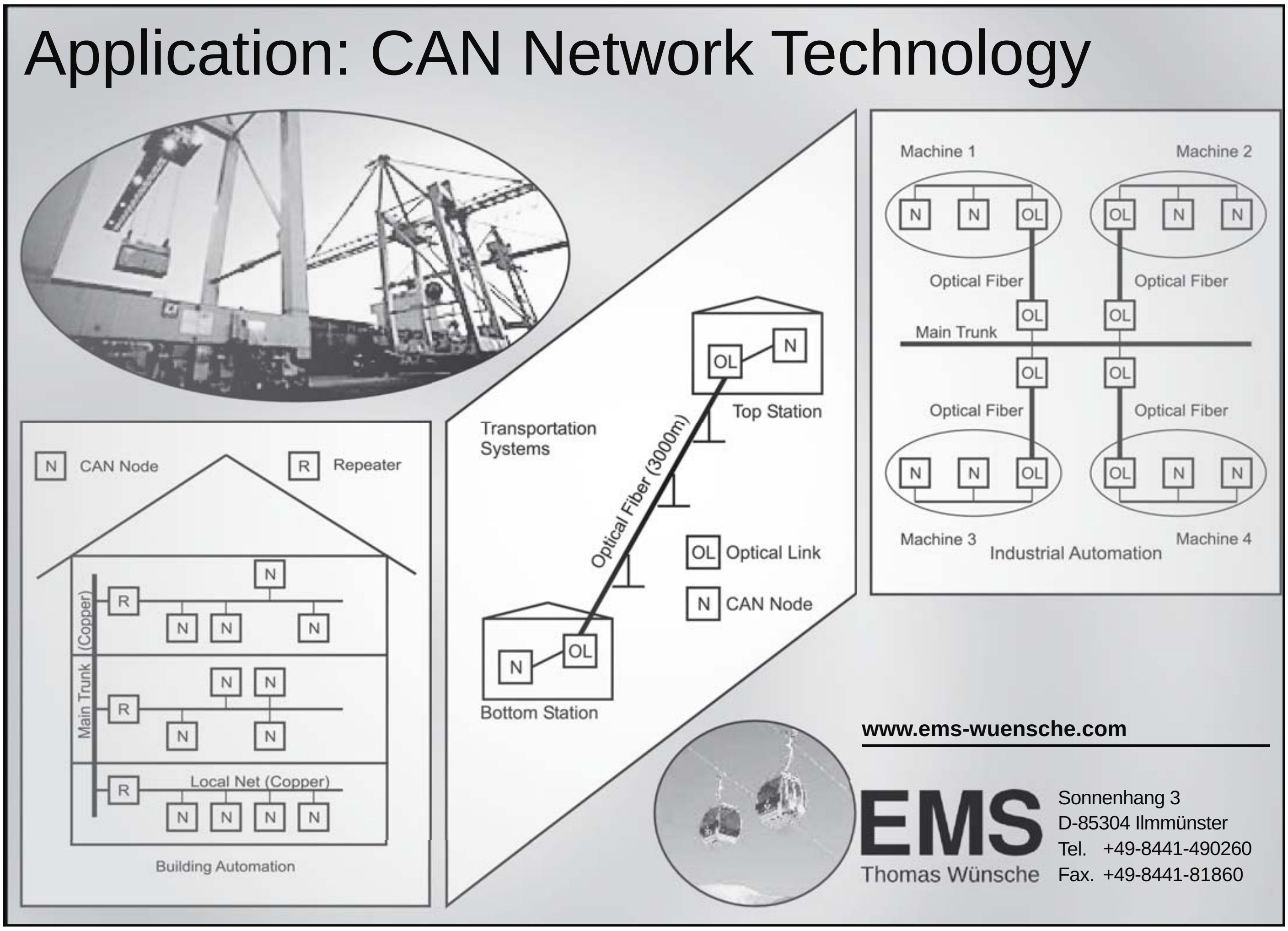
Using additional hard- and software functions, Yaskawa has fine-tuned the proven series V1000 frequency inverters in the vacuum pumps perfectly for the application, enabling the inverter to perform functions that go beyond simple drive control: For example, a highly accurate evaluation of the pump's ongoing operating data has been integrated into the inverter's internal terminal board, optimizing the efficient use of the pump's range of performance. That is, the pumps can work with higher efficiency without requiring additional electronics. The terminal board offers further possibilities: Inverter swapping is made simple although it is rather improbable that these units, which are designed for a service life of 10 years of continuous operation (at 80% nominal power), would ever become a source of failure. Should this happen against all expectations, then a replacement unit can quickly be inserted. To do so, the terminal board that stores all parameters and ancillary functions is simply inserted into the new inverter without even having to disconnect the control lines. The vacuum pump will therefore only suffer minimal downtime.

The inverter's software was also been fine-tuned perfectly for the application. A number of pump-specific functions and protection functions were integrated. If for example a valve is closing, then the frequency inverter will react quickly and in full autonomy to the resulting load change. Even shortest cycle times that translate into regular load changes can be supported in this way. Indeed, the V1000 frequency inverters offer many attractive features as a standard that are convincing not only for vacuum experts, but also for many users in other areas. Due to their compact dimensions, these frequency inverters are among the world's smallest units and only need very little space for installation. A number of different housing variants are available such as a standard IP20-rated case and various finless models for external cooling systems as well as IP66-rated variants.

Figure 3: Due to their compact dimensions, the frequency inverters are among the smallest units in the world and only need very little installation volume; beside the IP20-rated enclosure, finless models are available for external cooling systems as well as variants, which meet the IP66 protection requirements

High power from a small package

The inverter features high-power in spite of its compact design: An overload of up to 150% is possible in heavy-duty mode. The drive can work with an overload of 120% in normal duty mode for applications that only require small overloads. In this way, a smaller drive can perform the task for which normally a larger one would be required. The user can select between open loop vector and U/f control techniques, and the inverter's communication capabilities leave nothing to be desired since all common bus systems are supported for a simple integration into this superordinate control networks. This includes the CAN-based higher-layer protocols CANopen and DeviceNet. These interfaces will enable a seamless integration of drive technology into the user's modern automation environment, opening up interesting opportunities for machine builders.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Automatic deployment of IEC 61499 function blocks

Jens Frieben and Dr. Matthias Tichy

Authors
M. Sc. Jens Frieben
jens.frieben@ipt.fraunhofer.de

Fraunhofer IPT
Project Group
Mechatronic Systems Design
Zukunftsmeile 1
33102 Paderborn
(Germany)

Dr. Matthias Tichy
Software Engineering Group
University of Paderborn
Warburger Str. 100
33098 Paderborn
(Germany)

Links
www.ipt.fraunhofer.de
www.uni-paderborn.de

CANopen SIG 61499
End of 2011, some CiA members have initiated a CANopen SIG, which specifies the usage of IEC 61499 compliant controllers communicating via CANopen networks.

In our work, we extended the IEC 61499 standard to allow an automated mapping of function blocks (FB) to devices. Additional attributes, like memory consumption, worst-case-execution-time or network delay, are added to the IEC 61499 standard. Via restrictions, like end-to-end deadlines or maximum bandwidth usage, the engineer is able to ensure system properties according to the requirements. All data is afterwards converted to a linear program, which is executed by a solver to find a feasible deployment. This approach yields three important advantages: First, all function blocks of the application are mapped automatically to devices.

Depending on the size and complexity of the application, this can speed up the development and prevent the selection of infeasible solutions, even before testing. Second, is the engineer is able to define end-to-end response times, which are strictly adhered when computing a deployment - an important feature when designing safety-critical systems. Third, a linear program to find feasible solutions also allows the search for optimal solutions regarding given objectives e.g. execution times or communication overhead. Finally, our approach automatically creates the routing functionality that is necessary for distributing communicating function blocks across different network segments. Depending on the used modeling tool, these elements must otherwise be created manually.

To evaluate our concepts, a prototype has been developed which allows the engineer to specify additional attributes and restrictions. It uses a constraint solver to find feasible or optimal deployments from which IEC 61499 compatible mappings and the according communication function blocks for routing purposes are generated.

Fundamentals

The IEC 61499 standard incorporates several new concepts and approaches for programming PLC. One of these new features is its object-oriented approach that allows the distribution of functionality onto several devices in a network. The three main parts of new IEC Systems are the applications, the hardware (devices and communication segments) and a mapping as shown in Figure 1.

An application consists of one or many function blocks that send events and data to communicate with each other. A function block (short FB) is an abstract representation of functionality and has to be instantiated for use. Figure 2 shows an instance of the voter function block named RedundancyVoter1. If the event vote is triggered, the three data inputs in1, in2, in3 are used in the function blocks internal algorithms to compute a value that will be set to the output port result. Other function blocks use this data the moment they get the output event *result Ready*. This way, complex applications are created by interconnecting different function blocks. There are also different types of function blocks, like the Service Interface Function Block (SIFB). The SIFB represents an interface to underlying hardware like actuator or sensors. This abstraction makes it easy to access hardware functionality by just reading the output and sending events to the FB.

The second part, the hardware of an IEC 61499 system consists of several devices connected by segments and links. A segment represents a communication medium like Ethernet. A link attaches a device to a segment. Each device has resources with runtime environments in which the ▷

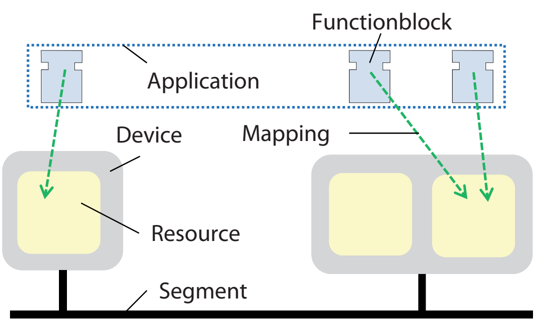

Figure 1: Important parts of the IEC 61499 standard

Abstract

Modern applications for programmable logic controllers (PLC) have to fulfill a broader range of functionality and more complex tasks than it was necessary a few years ago. The IEC 61499 standard has been developed to simplify PLC programming. It supports reusability, interoperability and offers an object-oriented approach for easy extension of existing applications. One way to achieve this extensibility is to split the application onto several devices, for which the standard provides a generic model for distributed systems. Currently, this mapping of software components, called function blocks, onto devices has to be done manually. End-to-end deadlines or other properties, like communication overhead or bandwidth restrictions, have to be checked via extensive testing or simulation. This is a time consuming and error prone task for the engineer.

function blocks are instantiated and executed. They also provide interfaces to the communication systems and to the device specific services.

The third part of an IEC system is the mapping, which is used for allocating the function blocks defined in the applications onto the resources in the network. It is mandatory, that every FB is mapped to exactly one resource.

Automatic mapping of function blocks

In our work we extended the IEC 61499 standard to allow an automated mapping of function blocks to devices. In this section, a short introduction to the changes and additions are given, as well as details to the deployment process and the advantages this approach offers.

A function block has one or more internal algorithms that are used to fulfill a certain task. Depending on the input and current state of the function block, this task takes some time to be executed and the results propagated to the next FB.

For our work, we had to make some simplifications how the function blocks are executed and how long this will take. The IEC standard does not define the execution semantics of the function block on a resource, so vendors can implement alternative scheduling functions. In this article, we assume a first in/first out strategy and pessimistically assume that each FB will be executed last.

This assumption guarantees that regardless of the execution order, the required constraints on the end-to-end-deadlines hold. In addition to this, the execution time depends in most cases on the given input and algorithm. To work with a fixed value, we require worst case execution times (WCET) for each FB. These two simplifications allow us to handle the tasks addressed in this work more easily.

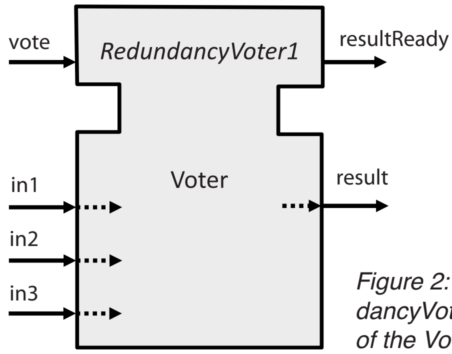

Figure 2: A RedundancyVoter1 instance of the Voter FB

The first step towards an automated deployment of FBs onto resources is to quantify the properties that influence the system. For example resources have limited memory or a specific performance that must be considered in a deployment. To cope with this, we added nine new attributes to different elements of the IEC System which are sufficient for our approach. Function blocks need to specify how much memory they will consume (*mem Use*) and how often they will communicate with each other (*comFreq*). The size of the data (*dataSize*) that is sent affects the deployment due to possible bandwidth restrictions. A value for the WCET (*execTime*) is important to be able to check if the reaction time restrictions can be adhered. The communication segments were augmented by the attributes delay, to specify the time needed to transmit the events and data, and the maximum bandwidth, which can be used to prevent lags in Ethernet-based networks by restricting the traffic on these segments. To the resources, three attributes were added. Performance to represent the processing power (e.g. 500 MHz), *devicetype* to restrict the types of FBs that can be instantiated on this particular hardware and *memCap* as an upper bound for the memory that can be allocated.

Storing additional information in the model of the IEC system is a prerequisite for an automated deployment approach. However, to restrict all possible distributions of function blocks to resources, more computational restrictions must be set up. An example for such a restriction is the *MaximumMemoryUse* rule, which states the simple fact: The sum of all FBs mapped onto a resource must be less or equal the resources memory capacity. A second example is a similar rule that forbids an algorithm to place incompatible FBs on resources based on the *devicetype* attribute.

When using SIFB these restrictions are also very important. Due to the fact that SIFB represent kind of access points to the hardware, they must be mapped to a specific resource. These predefined mappings can be enforced by a restriction.

To go one step we added additional concepts to adhere predefined end-to-end deadlines. In many application domains is it necessary to know exactly how long after a triggering event it will take until a certain reaction can be expected. Figure 3 shows an exemplary setting in which a *flowsensor* passes its data to an input/output compare. The comparer FB notifies the *pumpcontrol* immediately, if the values do not check out correctly. In that case, the pump control must send a stop-signal to the pump. The resulting reaction time can be calculated by adding each FBs WCET, the time to wait for other FBs on the same resource, the communica- ▷


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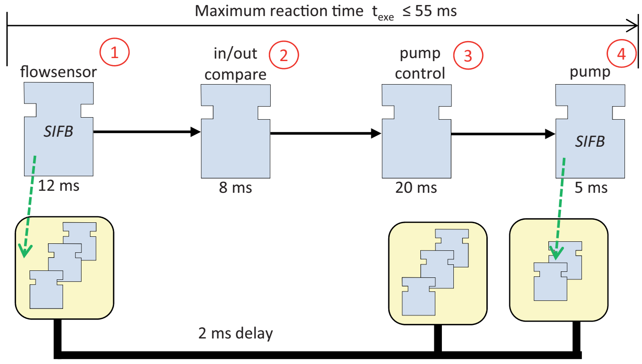

Figure 3: An execution chain of four FBs and its maximal reaction time

tion overhead and the delay on the network. To cope with this problem, we added *executionchains*. The engineer knows the critical path (from the sensor to the pump) and adds the FBs in this order to a list. Afterwards a maximum reaction time is set which must not be exceeded by the calculated reaction time.

A welcome side effect of computing a feasible deployment of function blocks onto hardware is the automatic generation of routing functionality. Currently most tools offer simple, automated functions that create *CommunicationSIFB* to handle the communication of function blocks between resources and devices. As soon as two communicating FBs are separated by a third segment, the engineer has to create them manually. By doing so, the additional FBs must be again considered in the timing analysis. This situation is shown in figure 4. The devices router1 and router2 relay the events and data from the sender to the receiver over a third segment, using Bluetooth as a medium. This scenario is not far-fetched, due to the recent developments towards smart factories [SMRFCR].

With the attributes and restriction already in use to compute a deployment, only a few constraints had to be added to extend the linear program to support routing. All *ComSIFB* that are needed for a communication over multiple segments can now be automatically generated.

There are various ways to compute a deployment and up to this point, we developed generalizable concepts that could be used with any of them. The two most common categories are heuristics or linear programming approaches. Heuristics usually use probability functions or randomness in different kinds of degree. Well-known heuristic approaches are Ant Colony Optimization [CHS02], Genetic Algorithms [Gol89] and Simulated Annealing [ZK10]. In our work, we aimed towards a fully repeatability technique to calculate a deployment. This led us to the use of a linear program, which can read, preprocessed and interpreted by an off-the-shelf constraint solver. As long as the input remains the same, a solver outputs won't differ from previous computations. Therefore, the IEC System, all its elements, attributes and restrictions had to be described in such a linear program before the actual deployment can be computed.

Linear programs are formal, textual descriptions of model and data of a problem that shall be solved. There are many languages for different solvers tailored for specific purposes. In our approach we used the optimization programming language (OPL) of IBM's commercial ILOG CPLEX [IBM] tool, because it is very close to a plain mathematical formalization.

The first step is to convert the IEC system into a format that the solver can process. Every FB, resource, connection between FBs and segments are represented as an ID and its attributes that are needed to compute the deployment.

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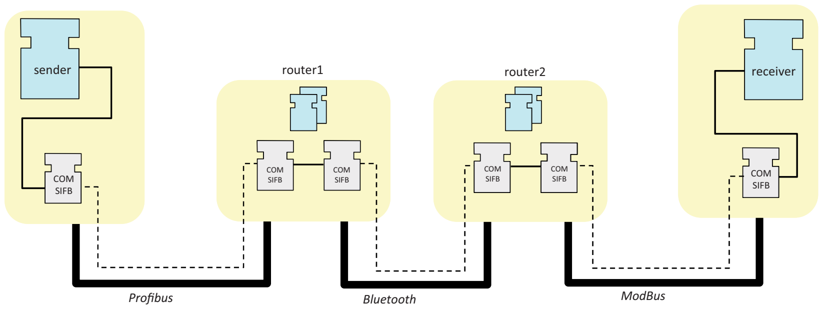

Figure 4: Routing through two segments

$$\forall\, r \in Res: \sum_{f \in FB} FB2ResMap(f,r) * memUse(f) \leq memCap(r)$$

Definition 1: Formal definition of the MaximumMemoryUse contraint.

The next step is to define the constraints that must be adhered. An example of such a constraint is the already introduced *MaximumMemoryUse*, which ensures that the memory capacity of a resource is never exceeded. In our work, every constraint has been specified in a solver independent, mathematical form and in OPL syntax. This allows us to easily create linear programs in different languages or even go back and specify appropriate formulas for the heuristic approaches.

First, the *MaximumMemoryUse* constraint is shown in formal syntax. The constraint uses functions to access attributes, like *memUse(f)* to get the memory use of the function block named f. The *FB2ResMaps(f,r)* is a true-false variable that is true if FB f is mapped onto resource r. This way it is easy to sum up the already used memory on the resource. An example of such a constraint is the already introduced MaximumMemoryUse (Definition 1), which ensures that the memory cacacity of a recourse is never exceeded.

The constraint written in OPL (Listing 1) is quite similar to the mathematical definition. Attributes can be accessed via the dot notation, e.g. the *memCap* value from the resource named r. Overall 18 constraints had to be implemented to force a correct deployment.

An important feature of using a linear program to compute a deployment, is that it provides the possibility to not find just one feasible, but an optimal deployment for a specific objective. In our work we used primarily the *executionChains* to minimize reaction times on predefined end-to-end deadlines or to minimize the bandwidth on segments.

In a linear program only one objective function can be defined, but there are often ways to combine different goals into one formula. These formulas are quite similar to the already introduced restrictions, but are supplemented by a *minimize* or *maximize* statement. Listing 2 shows the objective function for minimizing the reaction times. The sum adds the values for the different chain times consisting of reaction times, delays and the *ComSIFBs*. With the use of the minimize statement, the solver tries to find the smallest value of this sum.

Minimizing the reaction time is useful to reduce for example the cycle time of processing steps, which can lead to improved throughput in a factory. A major drawback of using an objective function is the increased computation time. Despite many well-developed techniques to solve linear programs, searching for an optimal solution is still a very time consuming task and might take up multiple times longer than any other feasible solution.

There are various optimization goals that can be implemented. It is for example possible to bypass unreliable communication media or in some cases, a load balancing might be required to use low-performance devices which are only battery powered and have to safe energy.

Concept evaluation

To evaluate the concepts presented in this work, a prototype has been implemented and used to compute deployments. The goal was to model an IEC system, define the additional attributes, restrictions, optimizations, and calculate an optimized deployment that fulfills all requirements and restrictions.

The IEC System including all its elements like FBs, resources and segments were created and ▷

```
constraints {      /* Constraint:  MaximumMemoryUse */
    forall(r in resources)
        sum(f in functionblocks) FB2ResMap[f,r] * f.memUse <= r.memCap
}
```

Listing 2: Objective function to minimize the reaction time of execution chains

```
minimize
   sum(c in chains )
      (sum ( r in resources )
         (resInChain [r,c]∗sum(f in functionblocks) FB2ResMap[ f,r]∗ f.execTime)
         + (sum(l1 in functionblockLinks , rescon in resourceConnections ) linkInChain [l1,c]
                                                    ∗ FBLink2ConMap[l1,rescon] ∗ rescon.delay )
         + (sum(l2 in functionblockLinks , r2 in resources) linkInChain [l2,c]
                                                    ∗ router [l2,r2] ∗ sumResExecTime [r2]) ) ;
```

Listing 1: MaximumMemoryUse constraint in OPL syntax

Conclusion

Manually mapping function blocks onto resources can be a time consuming and error prone task. Main reasons for this are usually the sheer amount of elements that have to be managed or the restrictions implied by the requirements. In our work we showed an approach to augment an existing IEC system with new attributes and restrictions. Based on this information, a constraint solver is used to create feasible deployments, which satisfy the given requirements like end-to-end deadlines. In addition to this we are able to find optimal mappings with respect to a specified optimization goal. Due to the preprocessing and formalization of the IEC system we are still flexible enough to later on exchange the linear program by a heuristic approach. Finally, an automated routing functionality has been added by making simple additions to the restrictions used by the solver. The concepts we showed help to make another step towards a more user friendly and computer aided development environment for IEC 61499 systems.

modeled with a commercial tool. As defined by the standard, all information must be stored as xml files, which could be read and preprocessed by our tool. As a result, we are able to generate a formal, machine-readable model of the system. During this process, several shortcomings of the current IEC 61499 standard had to be dealt with like redundant information or identical names for type definitions.

We created a prototype that allows the import of the system, set the values for the new attributes and create the chains in a graphical editor. Afterwards, the linear program is generated and executed by the solver. The resulting output is analyzed and the function blocks for the routing are added to the system.

Based on this prototype, we executed a series of tests to gather information about the runtime of the solver. To get representative data, we randomly generated IEC models in multiple versions and specific setups. These setups included, among other factors, different numbers of function blocks or resources, varying sizes of chains and with or without an objective function. Afterwards, we measured the time it took the solver to compute a deployment. All tests showed an exponential runtime depending on the size of the model.

First, simple scaling tests were run, in which no chains, routing or optimizations were set up. Scaling only one factor, function blocks or resources, resulted in faster computations in comparison to setups in which both factors were scaled simultaneously. This showed how the complexity of the input model influenced the overall computation time. Adding more communication segments to increase the routing complexity resulted only in a minor raise in the runtime of the solver. The use of execution chains and an objective function had a much more severe impact. The tests showed that adding multiple execution chains to the linear program resulted in twice as long computation times. The determination of an optimal solution is by far the most time-consuming setup and usually takes three to five times longer to compute than a model with routing, multiple segments and execution chains.

The prototype proves that the concepts we developed can be applied and used to deploy function blocks onto resources. However, there still a great potential to of performance improvements to speed up the computation process which are partially addressed in the next section.

Future work

But there are still some issues left open to investigate. For example must the simplifications that had been made to better cope with the WCET be analyzed in more detail. Timing analysis in general is an interesting topic that several research groups are currently investigating. Some problems caused by the non-formal or incomplete definition of the IEC 61499 standard complicate the creation of tools or the external processing of the IEC systems. Workarounds are used vendor specific and therefore cancel out the aim of an independent programming standard.

The exponential runtime of the solver is still a problem for large systems. Here, more techniques should be incorporated to speed up the process. Possible solutions to handle the execution time problems might be heuristic approaches, to hierarchically structure the system or to use partial mapping techniques in combination with clustering approaches. ◄

CANopen and FDT

Manfred Brill

Author
Manfred Brill
SW Consistency Manager
Schneider Electric Automation GmbH
info@schneider-electric.com

Link
www.schneider-electric.com

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Application Management, Device Type Manager, FDT Technology, Field Device Frame, IEC standardization

Abstract
The FDT technology was introduced in process automation ten years ago. Now, more and more supporters in factory automation are embracing it. The technology allows the integrated management of devices from different vendors connected to different field-busses. This article gives an overview on the technology, and describes how it can be used in CANopen environments. It will explain the different types of DTMs (Device Type Manager), and the usage of CANopen-EDS.

End-users are demanding a single engineering environment to manage, commission, and configure any field device, from any device manufacturer, and connected to any communication technology. They want the flexibility to select any supplier's product and not be restricted to a specific vendor. End-users need an "open" technology that preserves the investments made in the field and changes of the installed base has to be avoided. They demand a technology that enables them to make use of any field device without restrictions.

They want to be able to select the best device fit for their application and access all the powerful native features of modern devices, without restriction imposed by the integration to a specific system. End-users need an open technology that preserves the investments made in installed field devices. Replacement or costly upgrades of the installed base have to be avoided. Seamless data exchange from devices to asset management applications is also required by end users.

Vendors do not want to adapt their software to different engineering environments. There shall be a single component supporting the capabilities of the device, which interoperates with many host-systems.

Broadly speaking, the FDT system can be compared to the printer driver system known from office applications. The printer is delivered with the corresponding driver. That driver implements standardized interfaces so that any office application can make use of it. In FDT, the hardware (the field device in this case) is delivered with a driver called Device Type Manager (DTM), which has the standardized FDT interface. This allows any FDT-enabled application (so-called FDT Frame Application) to use it. FDT specifies these standardized software interfaces. They were defined in a general way, so that it is possible to design engineering environments that could manage any device from any manufacturer using an arbitrary field bus protocol as required by end users (Figure 1).

The device vendor provides the interfaces for the DTM, including communication capabilities to the device itself but also to other DTMs. The Device Type Manager of a device from one vendor is thus able to interact with the Device Type Manager of a device from another vendor. This allows connecting products of different vendors, to have greater flexibility. It is possible to select the device best fitting the demands of the application, independent from vendor or communication protocol.

A change of the current installed base is not required. The existing network of buses, communication devices and field devices can be mapped to the FDT engineering system. The only thing needed is the Device Type Manager component representing the devices in the FDT Frame Application.

FDT is not limited to a predefined set of description semantics or graphic elements. Anything that can be done with software is possible inside the DTM. ▷

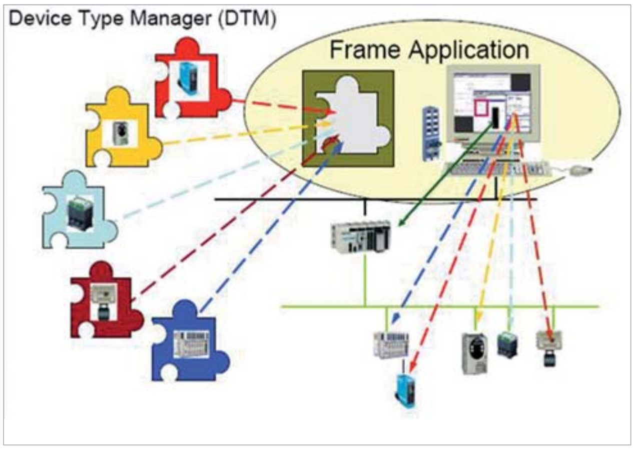


Figure 1: DTMs from different vendors can run in one FDT Frame Application

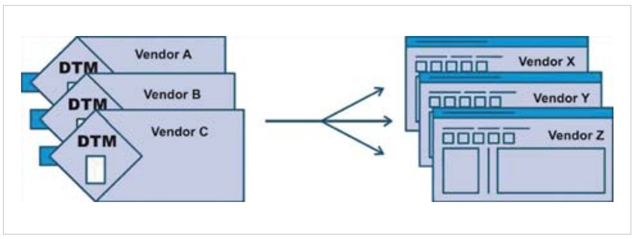
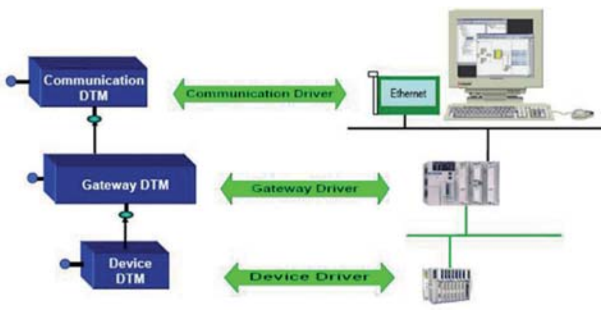


Figure 2: Any DTM can run in any FDT Frame Application

Figure 3: DTM types



This allows device vendors to implement any functionality they find useful for their customers and makes it easier for automation suppliers to evolve their software with the state of the art in communication and information technology. Investments in automation are protected well into the future.

Automation suppliers no longer have to worry about integration problems. Development costs due to diverse environments in host systems and field devices, which used to require customized interfaces for every combination, cease to exist. Resources can be invested in specialized, differentiated features that bring benefits to the end user.

FDT provides standard interfaces, which means that the DTM can be used either in automation systems or stand-alone asset management tools. The Device Type Manager is unique for each device type and needs to be built only once, thereby protecting vendors' investments (Figure 2). Its content is inaccessible to third parties and the vendor's know-how is protected.

A FDT Frame Application could be any tool, which provides the FDT interfaces to host a DTM. Examples of such tools are:

- Configuration tools to configure devices and system components
- Commissioning tools to set up devices in the field and download device-specific data
- Programming tools for PLCs
- Diagnostic tools to analyze device and system errors
- Asset Management tools to manage all the devices and components of a plant

In respect to FDT the Frame Application is responsible for the following tasks:

- Managing the catalog of installed DTMs
- Engineering of Topology
- Managing the lifecycle of a DTM
- Hosting the DTM User Interface
- Ensuring data persistency
- Printing documentation
- Managing Users
- Managing the audit trail
- … and more depending on the application type

The Device Type Manager

The Device Type Manager (DTM) is a software component developed by the device manufacturer containing device-specific application software. It encapsulates device-specific data, functions, and business rules. The DTM is typically supplied with the device. It is not a stand-alone tool. The DTM always needs a FDT Frame Application to run.

There are different types of DTMs. Figure 3 shows an example of a network topology and the equivalent structure of DTMs in the engineering tool. The DTM type depends on the device type the DTM represents. The access to the network, where the engineering tool is connected to is provided by a Communication DTM. This DTM allows the access to the network in a standard way.

A Gateway-DTM is responsible for the transformation of the protocol data from one network to the other. A Device-DTM represents the field device with all its capabilities.

A specific PLC tool Interface annex supports a deeper integration of FDT into PLC programming tools. With this interface it is possible to map process data communication technology independent to PLC variables.

The FDT Group has implemented a certification process for FDT products. Vendors can certify their DTMs and Frame Applications in seven accredited test sites around the world.

The FDT technology is the only one, which supports the integration of different vendor tools into one engineering environment and uses it with different field buses. This means the user can manage all the different field devices from a central engineering application and in a common and standardized way. This reduces the cost over the complete life-cycle of its plant. Due to the ability to cross network hierarchies in a heterogeneous network environment (called nested communication), it is possible to access a device at ▷

FDT Group

The FDT Group promotes the FDT technology. The data exchange between the FDT components is based on XML. Members of the international FDT Group have developed annexes for different communication technologies, where the services are selected and their XML format is described:

- *CANopen*
- *CC-Link*
- *CIP Networks (DeviceNet, EtherNet/IP and CompoNet)*
- *Foundation Fieldbus*
- *HART*
- *Interbus*
- *IO-Link*
- *Modbus SL and TCP*
- *Profibus DP/PA*
- *Profinet*
- *Sercos III*

For Ethercat is an annex under construction.

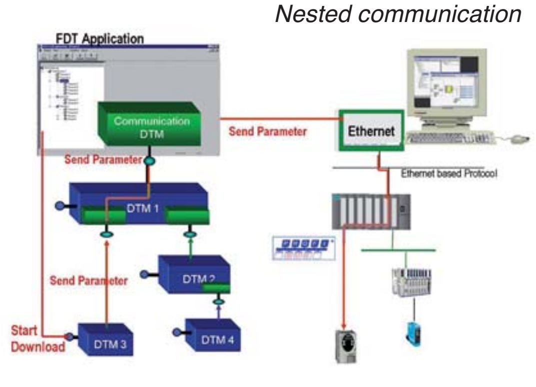


Figure 4: Nested communication

any level of the automation pyramid from a central point (Figure 4). With this ability it is possible to manage CANopen devices located at lower levels from higher levels of the automation pyramid (e.g. configuration, diagnosis) with no need access the device at its location. With FDT the administration of a complete plant is simplified and managed in a consistent way, it is possible to provide the automatic mapping of PDOs and there is no need to handle EDS file. The use of DTMs offers much more flexibility for device management than static device descriptions (e.g. GUI, dynamic data management). Figure 7 shows an example from a Drives DTM of Schneider Electric configuring a closed-loop control.

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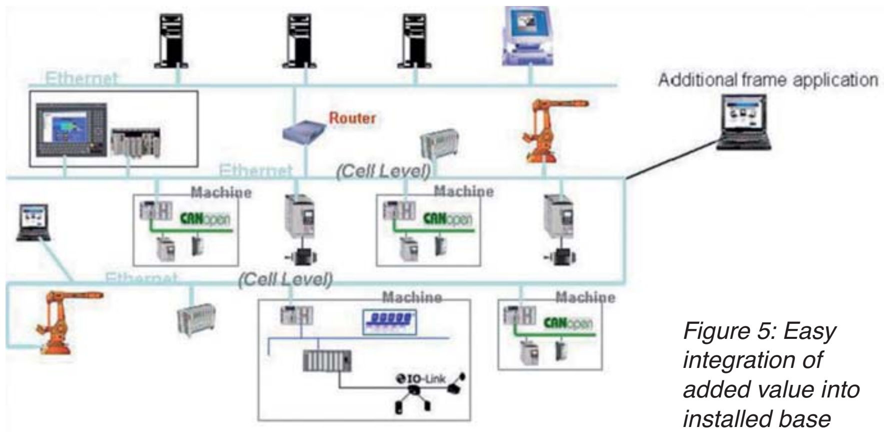


Figure 5: Easy integration of added value into installed base

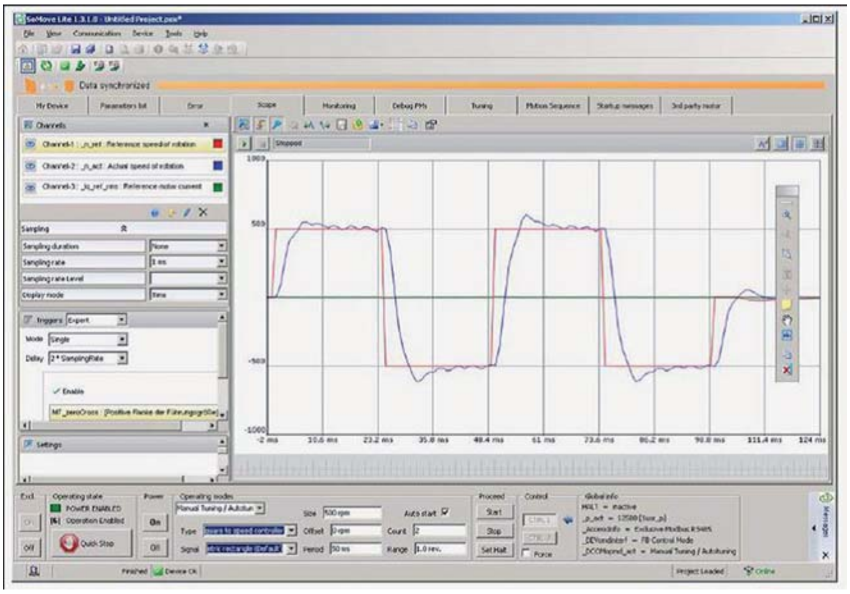


Figure 6: Capabilities using a DTM

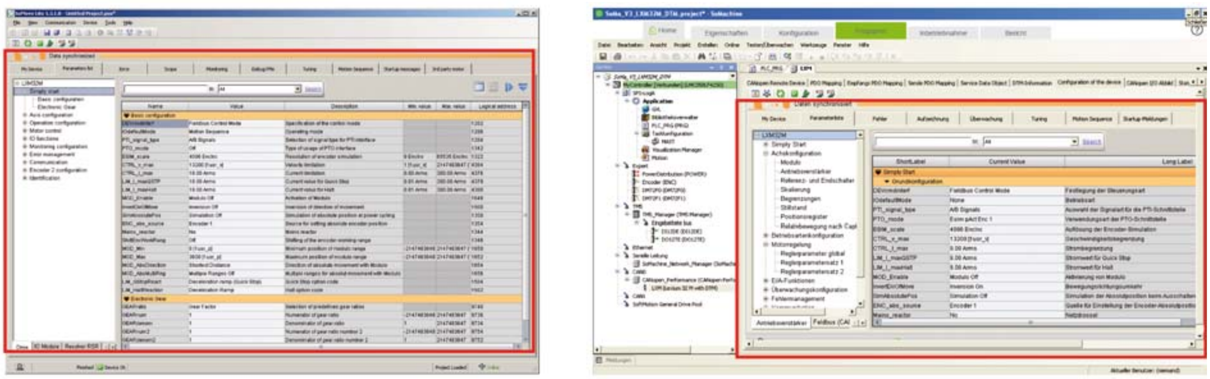


Figure 7: Lexium Drive DTM in the stand-alone and the PLC programming tool

Furthermore the FDT technology allows the end user to add additional applications in the installed base without changing the installed devices and networks. Figure 5 shows such an example where an additional frame application is added to the installed base, which could be used e.g. for diagnostic, asset management or predictive maintenance activities.

At Schneider Electric CANopen DTMs are used in different tools in the same manner. The tools provide a FDT interface (called FDT container), which allows running DTMs in a integrated way. There is e.g. a stand-alone tool called SoMove to configure single drives in a one-to-one connection. The same DTM can be used in a PLC programming tool. The use of the FDT technology helps to present the devices in different tools in a consistent manner. The red frame in Figure 7 shows the same Lexium Drive DTM in the two different tools.

FDT evolution

Today the FDT specification version 1.2.1 is used in the implementations. The FDT Group is currently finalizing the next step in the evolution of the technology. The version 2.0 will be released in April at the Hanover fair. The new version will be based on .NET und having a lot of improvements. The object model is simplified, the number of interfaces is reduced and performance aspects are taken into account. Beside this some new features are included which are important for tools used in factory automation. It is know possible to manage a physical topology (e.g. networks) aside the logical topology from version 1. It is also assured that the new specification guarantees backward compatibility that means the use of DTMs of version 1 and 2 in the same environment. ◀

Summary

The FDT Technology fulfills the needs of the end-user. It is the only technology, which allows the integration of field-device tools into one application, the so-called FDT Frame Application. With such an application the end user is able to manage its field devices in a consistent manner. Such a solution reduces its cost over the whole life cycle of a plant. As the technology is communication technology independent it offers a real value in our heterogeneous fieldbus world. CANopen is part of this world and can easily be used within an FDT Frame Application even if it is applied in a plant with other field busses. FDT can also be an enabler for improvements in existing plants (e.g. asset management, preventive maintenance) without the need to change the installed base. The FDT technology is standardized at IEC since July 2009 (IEC 62453) and was released as GB/T standard in China last November.

Common-mode effects in CAN networks

Steve Corrigan

Author
Steve Corrigan
Senior application engineer
support@kvaserinc.com

Kvaser (USA)
23881 Via Fabricante,
Suite 503
92691 Mission Viejo (CA)

Links
www.kvaser.com
www.kvaserinc.com

Common-mode problems are often found in the networked equipment typically found in CAN applications. Possible effects of this problem are intermittent reboots, lock-ups, random errors, or physical damage to electronic equipment. Interface cards, parallel ports, serial ports, and especially transceivers are prime targets for some form of failure if not designed to accommodate high levels of noise and power supply imbalance between CAN nodes due to common-mode voltage ground offset.

Differential balance and common-mode noise rejection

As the electromagnetic (EM) spectrum becomes more fully utilized by modern equipment, there is an increasing probability of interference in electronics that results from EM fields radiated by a wide range of devices. Due in part to the revolution in wireless electronics, EM interference is increasingly becoming a widespread concern.

Every electronic component has unique EM characteristics in which the inductance and capacitance of its circuit may develop a common-mode resonance that occurs at discrete frequencies in which emissions are amplified at some frequencies and attenuated at others. EM radiation links the antenna-like wires of a CAN network and generates common-mode noise on the twisted-pair bus lines. However, differential signaling allows CAN to operate in the presence of this common-mode EM noise and at the same time minimize its own radiated emissions. CAN's differential signaling allows the receiver to reject common-mode noise that occurs within the differential input range of the device.

Common-mode noise rejection is a specific function of differential receivers, just as it is with other differential-input circuits such as operational amplifiers. Differential signal wires are physically close together and equally exposed to the same noise sources – noise common to each wire. The close proximity of the wires ensures that exposure to electromagnetic fields is nearly equal and common to each line, thereby canceling the differential influence from magnetic field coupling by reversing the polarity in adjacent loops of twist in twisted-pair wiring.

Common-mode noise due to capacitive, electromagnetic, or inductive coupling from extraneous sources of notable magnitude exist within the networks associated with many CAN applications. Noise from pulse motor controllers, switch-mode power supplies, or from old, ballast fluorescent lighting load are the typical sources of the noise that couple onto bus lines.

The CAN differential signal is the voltage difference between the CAN_H & CAN_L wires, equal to CAN_H – CAN_L. For a recessive bit, this is typically 0 V, and for a dominant bit is 2 V (high-speed transmission as specified in ISO 11898-2). Problems often occur when noise nearing this amplitude attaches itself to a bus signal. Unwanted noise of this magnitude often links the antenna-like bus lines of a CAN application as displayed in Figure 1.

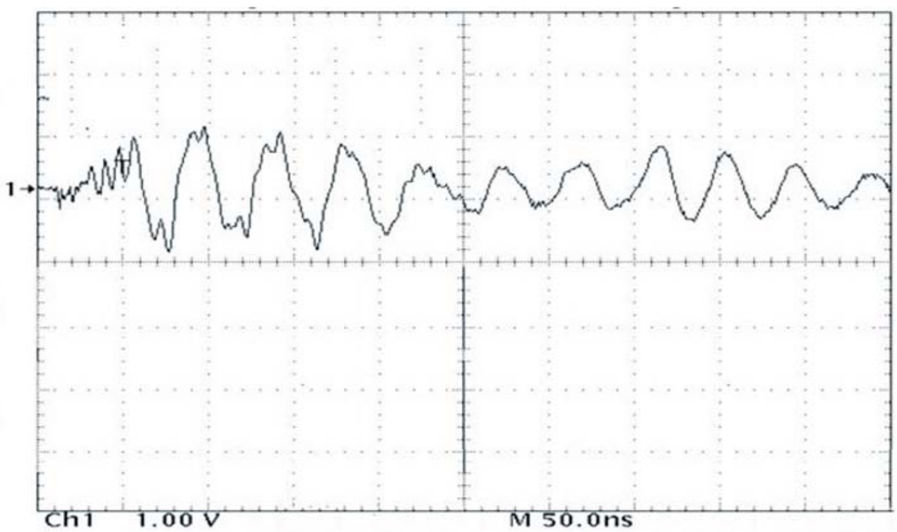


Figure 1: Noise coupled onto twisted-pair bus-lines

When CAN_H – CAN_L does not equal zero as shown in Figure 2, trouble begins. If each wire of a CAN line is not equally coupled by this noise and rejected differentially, a receiver may respond to common-mode noise as if it were data on a bus and send meaningless data to a controller. It is noteworthy that the TI SN65HVD251 datasheet shows how the transceiver is actually tested for coupled noise rejection.

A common-mode noise solution

Passive filtering termination circuits can attenuate the common-mode noise seen at the receiver terminals – common-mode chokes, or baluns are often used for this purpose. However, split termination resistors with a capacitor to ground from the center point, are successfully being used.

To facilitate this function as defined in ISO 11898-5 (high-speed transmission with low-power mode), CAN transceivers such as TI's SN65HVD1040 provide a "Split" pin specifically designed for this purpose with the same common-mode voltage operation and ESD protection as the bus-pins.

Split-termination is used to filter high frequency common-mode noise from the bus lines with the termination technique shown in Figure 3. This is accomplished with a coupling capacitor at the center-tap of two 60-Ω termination resistors. This configuration couples high frequency noise to a solid ground potential.

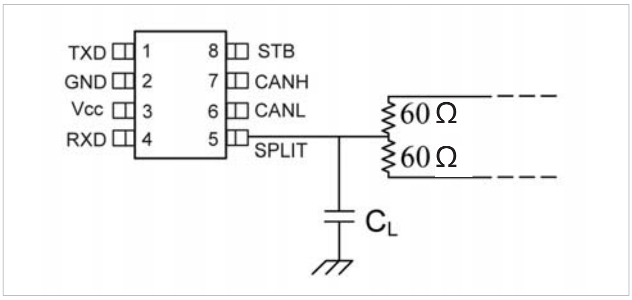


Figure 3: Split-termination filter

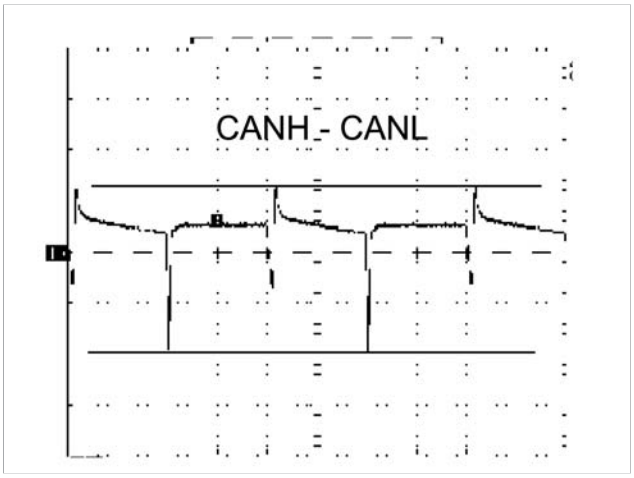


Figure 2: Common-mode noise

In the split-termination configuration, a differential signal can be understood as the two sources in Figure 4 in series with a center-tap to ground. The upper source drives the red current from its positive pole to its negative pole via ground. The lower source drives the blue current from its positive pole (ground) to its negative pole. For an ideal differential symmetrical source, these ground currents cancel one another. The grey dashed current now represents the resulting current flow, and there is no influence from the split-termination capacitor in Figure 3 on the differential signal.

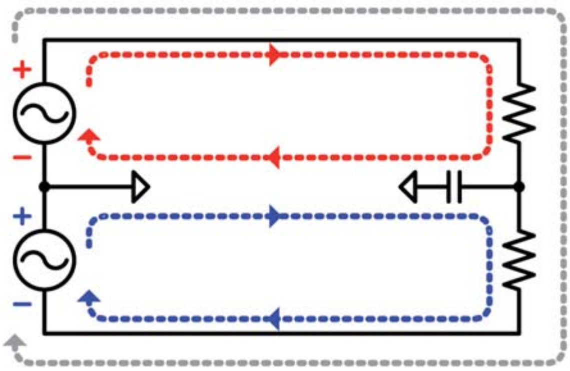


Figure 4: The differential signal with split-termination

A typical value for CL in Figure 3 as recommended by the ISO 11898-5 standard is 4,7 nF. The capacitor does not limit the bandwidth of the differential signal since it only affects a common-mode noise. This function is being employed so successfully as displayed in Figures 5 and 6 that many designers no longer require chokes.

Common-mode voltage offset

Common-mode voltage offset describes a condition, in which the ground-pin of an electrical outlet thought to be 0 V is found to be at a high DC-voltage level. Currents that flow between the ground plane and earth due to AC primary or secondary neutral currents in a power-distribution system, produce a potential difference between the neutral and ground plane. This ▷

Abstract

The term "common-mode" is often misunderstood and used in a variety of topics. Although many common-mode discussions are centered around amplifiers and data converters, it frequently plays a critical role in the operation of a CAN network. Common-mode problems arise from several sources and are often the cause of trouble in many circuits. This discussion centers on the common-mode noise and common-mode voltage offsets that plague many CAN applications.

Balun

A balun is a type of electrical transformer that can convert electrical signals that are balanced about ground (differential) to signals that are unbalanced (single-ended), and the reverse. They are also often used to connect lines of differing impedance. The origin of the word balun is bal(ance) + un(balance). Source: Wikipedia

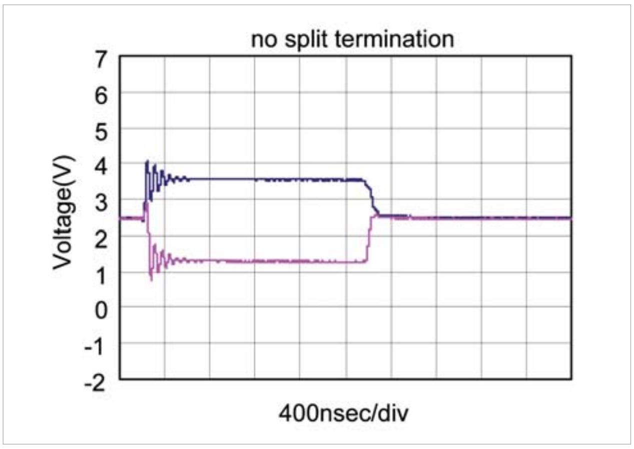


Figure 5: Differential signal with noise

ground offset potential difference between electric power outlet locations can vary widely across any building and must be checked by designers in any CAN application.

Ground voltage offset can vary from several volts to several tens of volts with the greatest differentials found in single-phase or 3-phase Y-distribution systems. In these applications, the portion of neutral current flowing in the earth can be 10% to 70% of the total current flowing in the primary circuit. Voltage measurements between ground points have been reported as high as 65 V between widely separated electrical outlets with disastrous effects on semiconductor products.

CAN transceiver often have to operate in such harsh environments and although the ISO 11898-2 standard specifies operation from -2 V to 7 V, transceivers such as Texas Instruments' SN65HVD251 operate with -7 V to 12 V common-mode operating range. The differential CAN signal rides an offset voltage as if floating on water until a -7 V or 12 V limit is reached. At this time the transceiver shuts down into a self-protecting high-impedance state and remains safe to 36 V for an unlimited period of time.

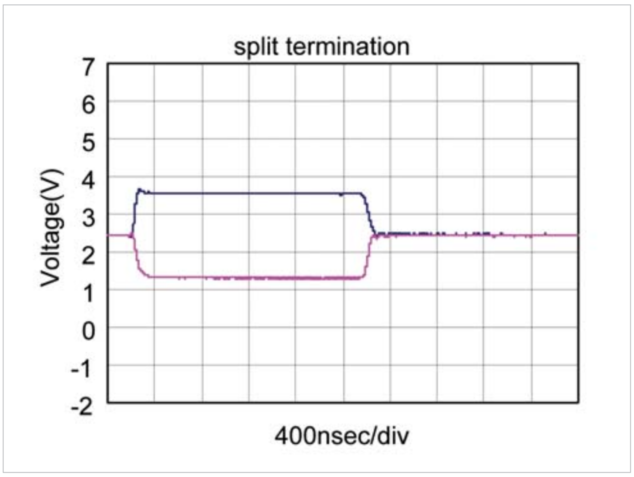


Figure 6: Split-termination filtered differential signal

A common-mode voltage offset solution

In order that the current required from an active CAN driver be limited to a practical value while driving a signal into 12 V of common-mode voltage, the loading effect of any combination of passive receivers and transceivers on a bus should be held to a minimum by restricting the common-mode voltage present. If the amount of DC-current that a device sources or sinks to a bus over the -7 V to 12 V range of common-mode operation is kept to a minimum, the number of nodes that can be added to the bus increases dramatically.

The most popular defense against the varied and problematic ground offset voltage is the practice of carrying the power and ground wires along with the CAN signal wires as shown in Figure 7. If this configuration is used, over a hundred nodes may easily be added to a bus. Several power supplies are often required in large applications and are most efficiently located together in the center of the location and grounded to a common return. Equipment too large to operate from these supplies are connected to a separate power supply, then isolated from the bus lines with digital isolators such as TI's ISO7221. ◀

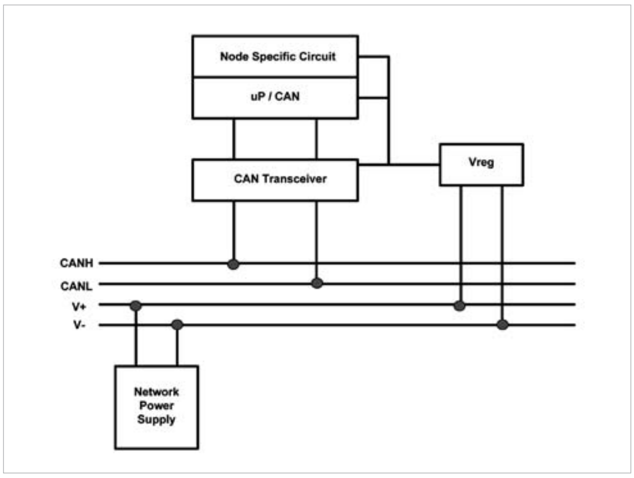


Figure 7: A common-mode voltage solution

Conclusion

The increasing complexity of manufacturing requirements along with demands for flexible, intelligent and fault-tolerant control systems are moving away from the traditional, sequential and centralized 4-20 mA type solutions. This is especially due to the lack of flexibility of these older systems with respect to a quick adaptation on unexpected and continual changes in the manufacturing environment.

CAN common-mode tolerance and flexibility not only brings the ability of integrating of new components into a system or removal of existing ones from a system at runtime, but its high degree of fault confinement minimizes the possibility of module failure and costly downtime in a system.

CAN – vintage, not obsolete!

Christian Schlegel

Industrial Ethernet is the talk of the day and the list of its promises is impressive: high data rates, long cable distances, and cost-efficient standard cables and plugs make Ethernet technology seem the communication medium of the future for automation manufacturers and users. While the benefits cannot be denied, Industrial Ethernet systems are not necessarily the best communication solution for each and every application.

CAN is still a very simple, flexible, and powerful network technology which, considering its low costs, is an unrivaled solution for many applications. As a development service provider who deals with all communication systems, we have many customers who, in view of the ever increasing demand for modular machine and plant designs, wish to decentralize their systems. A good many of them ask us, whether it would not be the right opportunity for a switch to an Ethernet-based data infrastructure. This question seems to indicate a diffuse doubt whether CAN or CAN-based field-buses are still up to date, i.e. can satisfy today's requirements. Our answer is that CAN is anything but obsolete. We counter reservations by preparing a requirement specification and a rough estimate which we use to illustrate two points: firstly, that the data rate provided by CAN and the permissible cable lengths are more than sufficient for a large part of the planned applications, and secondly, that CAN-based communication solutions are the most affordable by far. Indeed, in most cases higher costs would be the only discernible effect of a decision for Ethernet.

Let us look at a typical example from medical technology: a dental laboratory technology manufacturer requires a control network for a dentist's chair and the accompanying treatment unit. He inquires after Industrial Ethernet. We list the requirements, e.g. the drive control for the adjustment of seat and backrest and for drills and pumps. CAN easily covers the necessary data rate. And the cable lengths are no problem for CAN either. Choosing Ethernet, on the other hand, would lead to significantly higher costs for plugs, cables, and switches, without any advantages for the application. And what can we say in terms of sustainability? We find no drawbacks in a decision for CAN, on the contrary. CAN keeps gaining ground, as it is nowhere near its zenith. In Asia and the USA especially, the network technology enjoys a growing number of deployments in various industries. However, some customers are not convinced, yet: what if the application has to be expanded at some future date? Would the limitations typical of CAN not prevent a free network extension? They would not – the decision for CAN is not a one-way track.

CAN overtaking – the well-established technology will continue to be the first choice in many applications

If required, CAN-based applications can be easily integrated into higher-level Ethernet networks as subordinate networks. And the migration from CAN to the real-time Ethernet systems Ethercat and Ethernet Powerlink, which integrate the established CANopen mechanisms in the application layer and are therefore sometimes called "CANopen over Ethernet", is likewise possible. Admittedly, we at Ixxat make money by selling CAN technology – we trade a wide range of interface cards, topology components, software, and various tools for analysis, configuration, and for testing CAN networks. However, we also provide development services for various Industrial Ethernet systems and supply many products for this segment, too. Apart from purely factual considerations, we therefore have no reason to prefer one system over another. For an engineer the superior technology might be more attractive. Yet, if the technologic advantages cannot take effect because they are not required for an application, the accountant should decide instead of the engineer – sensibly, the lower-cost product often comes out on top. And that will mean CAN for a long time yet. ◀

Author
Christian Schlegel
Managing Director
Ixxat Automation GmbH
Leibnizstr. 15
88250 Weingarten
(Germany)

info@ixxat.de

He is working with Ixxat from the beginning, and was also with the predecessor STZP (Steinbeis Transferzentrum Prozessautomation). Since 20 years, he has participated in CiA technical working groups, some years he was elected as CiA Technical Director.

Link
www.ixxat.de

Tapping the full potential of CAN with topology components

Company
Ixxat Automation GmbH
Leibnizstr. 15
88250 Weingarten
(Germany)
info@ixxat.de

Link
www.ixxat.de

In CAN networks the underlying transport protocol sets structural limits to the system in general applications. CAN currently manages a 1 Mbit/s transmission rate, given that the overall network cable length does not exceed 25 m. If longer lines are necessary, the transmission rate must be reduced – the longer the distance, the higher the speed loss. However, with suitable topology components, high bandwidths can be realized even in large networks. Specific benefits of various solutions will be outlined in the following.

CAN networks can be extended and made more flexible by means of various components. For example, repeaters enable star and tree structures instead of a simple daisy-chaining of bus nodes. Bridges and gateways, on the other hand, are mainly used for the physical extension of existing linear connections. With suitable components CAN networks can even be enabled for wireless communication.

Figure 1: With CAN topology components, high bandwidths are possible even in extensive CAN networks

Implementing stars, decoupling segments, connecting copper and optical fiber

CAN repeaters primarily serve the physical connection of two or more segments of a CAN bus system. Additionally, they allow for the implementation of tree and star topologies and long stubs. Repeaters and star couplers do not in general influence the real-time behavior of a system. An application scenario: three pitch controllers in a wind turbine shall communicate with the Master controller via CAN.

The standard line topology of CAN is not equal to the task. However, a CAN repeater enables star connections to the individual wind turbine blades. It also establishes galvanic isolation and thereby improves lightning protection. In case of unexpected failures in the network, faulty segments can be taken off the network by means of an integrated monitoring function in order to maintain reliable communication between the other network participants. As soon as the failure has been repaired, the restored segment is reconnected without interruptions. CAN systems linked via a repeater represent autonomous electrical segments with optimum signal termination – thus, topologies can be realized which would be impossible with a simple linear bus topology for the danger of electrical reflections.

The functional range of repeaters includes coupling different physical CAN layers, e.g., translating between high-speed and low-speed CAN or connecting copper cables and optical fibers. Furthermore, they improve EMC and dispersion behavior of CAN systems. For instance, galvanic isolation integrated in ICAN repeaters for up to 4 kV prevents the spreading of interferences through the network. By repeating the signals, the devices also filter errors caused by electromagnetic interferences or cable quality.

Extending transmission lines, filtering communication, establishing wireless communication

In contrast to CAN repeaters, which are not principally meant for the extension of line topologies, CAN bridges and CAN gateways directly support the increase of the maximum network size. CAN bridges can connect networks using different bit-rates or protocols. They are based on the store, (modify) and forward principle, receiving CAN messages from one network part and sending them via the other. Conversion and filter algorithms may be employed, enabling, e.g., protocol conversion between network parts.

Among other things, the integrated filter function allows for messages to be filtered before being converted from one network to the other in order to keep the bus load in the particular networks as low as possible. Bus arbitration of system subsections takes place absolutely independently, which enables the higher maximum network size mentioned at the outset. Building automation is an area where CAN bridges are employed particularly often, namely to connect distributed subnetworks. In buildings it is particularly important that installations can be flexibly adapted to ensure that CAN communication works smoothly with typical line topologies with limited stub lengths. Radio transmission may be implemented in applications where communication by wire is difficult, such as rotary tables. In this case, CANblue/Generic by Ixxat, which enables CAN data communication via Bluetooth, can be used for coupling. Data transmission occurs on layer 2 and is transparent. Therefore, this solution can be used with various CAN-based protocols from CANopen or DeviceNet to customer-specific variants. If several CANblue/Generic units are employed, the devices can be coupled dynamically. ▷

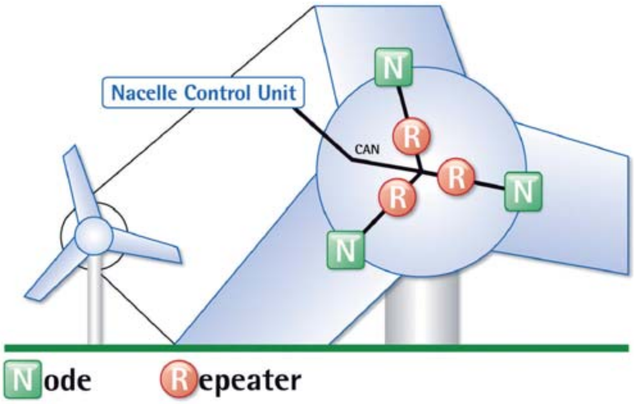


Figure 2: CAN repeaters enable star topologies in wind turbines

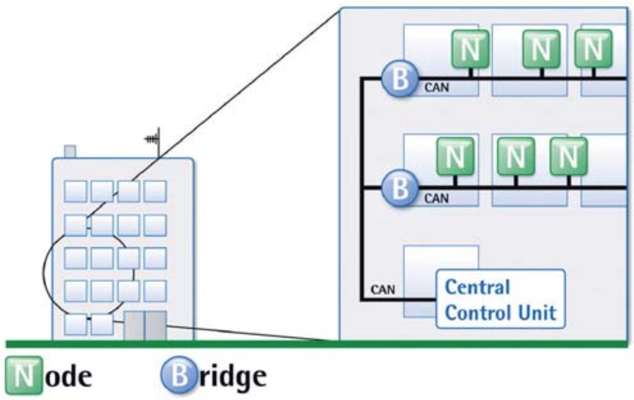


Figure 3: By means of bridges, cable lengths in CAN networks can be extended

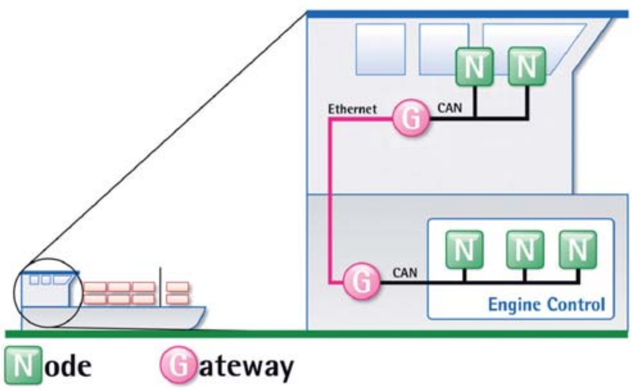


Figure 4: Coupling CAN systems via a transparent Ethernet link

Ixxat Automation

The company focuses on industrial communication systems based on CAN (CANopen, DeviceNet), Ethernet (Ethernet/IP, Profinet, Ethercat, Modbus-TCP), and TCP/IP with the associated transport protocols. Solutions for the automotive industry are mainly based on CAN (diagnosis protocols, SAE J1939), Flexray, and LIN. The product portfolio includes interface cards, test systems, analytical tools, and protocol software. Currently, the company employs a staff of 80, mostly electronics engineers and computer scientists. The German company has an ISO 9001-certified quality management system.

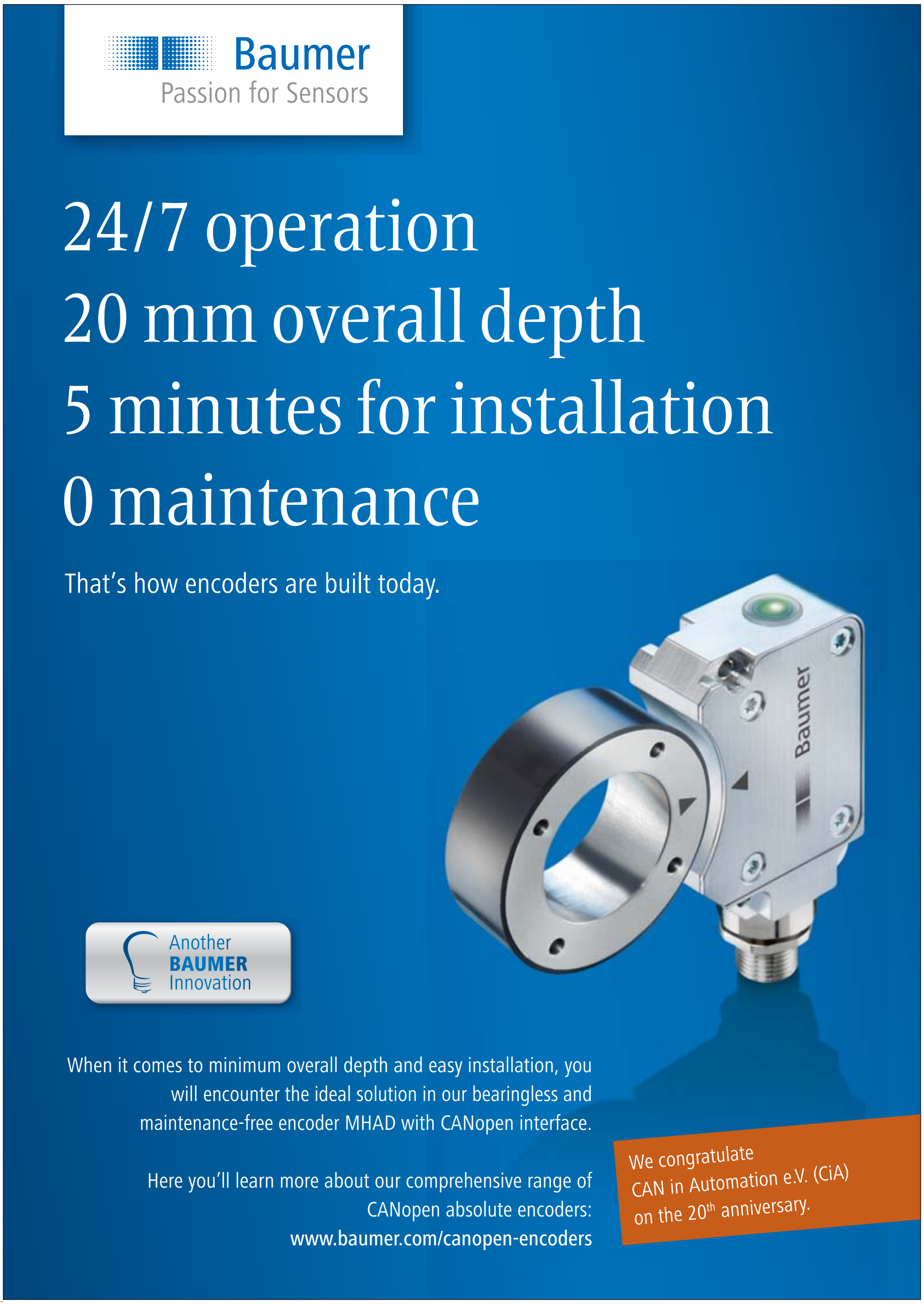
Conclusion

Topology components allow for CAN networks to be made much more flexible and to be optimized for various requirements. Thanks to various types of repeaters, bridges, and gateways the planning, installation, and operation effort is reduced, networks are less affected by outside interferences, and data trans-mission security increases significantly. Thus, topology components make CAN a versatile bus solution, which will keep on meeting the requirement of increasingly complex application scenarios.

Connecting CAN to Ethernet backbones

Gateways such as the CAN@net II/Generic allow for CAN networks to be easily connected to other network types, in particular Industrial Ethernet. This network coupling method in bridge mode is often employed if the two networks to be connected are not immediate neighbors. This kind of CAN bridge may be used on ships to connect higher-level controllers with CAN networks in order to enable efficient communication between the motor controller and bridge control. This bridge operating modus requires two CAN@net II/Generic devices. CAN messages are exchanged via TCP/IP; if required, filter tables can be filed. A comfortable PC tool with automatic device recognition is available for configuring TCP/IP communication parameters.

The bridge function is implemented and the CAN configuration parameters are entered via a web-server implemented on CAN@net II/Generic. However, bridge solutions serve not only the connection of CAN and Ethernet. Many applications require devices to be connected to CAN networks via a simple RS-232 interface. The CAN-GW100/RS-232 gateway is a comfortable solution for connection to the bus in CAN or CANopen operation mode. Technical implementation happens in CAN mode (layer 2); the received CAN data are transparently transmitted via RS-232. The data sent via RS-232 are packed into telegrams. There is one configurable identifier each for sending and receiving CAN data. In CANopen mode, CAN-GW100/RS-232 functions as a CANopen participant. Serial data are archived as byte stream objects in the manufacturer-specific object directory section and transmitted via PDO. ◄



Modular I/O devices support hot-plug function

Company
Systeme Helmholz GmbH
Hannberger Weg 2
91091 Großenseebach (Germany)
info@helmholz.de

Link
www.helmholz.com

Abstract
The TB20 I/O device family by Helmholz comes with CAN and CANopen interfaces. Details drawn from real-life experience – such as the deliberate design of the modules in three parts – ensure easy integration and configuration. The devices featuring analog and digital I/Os are hot-pluggable.

In industrial automation, input and output modules still predominantly incorporate the concept of a centrally controlled topology. This is the case even though it has long been known that decentrally wired alternatives can provide significant setup, maintenance and operational benefits. The TB20 I/O system is characterized by the influence of extensive customer feedback based on practical usage. This step towards our own decentralized I/O solution is not just a deliberate extension of the product range. More important is the fact that with decentralized modules, the components are smaller and therefore save space. The task of wiring everything together is significantly reduced. In addition, a single I/O system will suffice even in the case of different PLC systems. This, in turn, results in significant business opportunities for control systems for traffic management or building automation.

All technical features of TB20 are targeted at supporting the development aims of efficiency and optimal use. In real terms that means rapid and simple installation and maintenance. For example, the power module is already integrated into the bus coupler, and up to 64 modules can be connected to the coupler. The modules are made up of three parts: the basic module can be simply snapped onto the rail. The electronic module and the front connector are then clipped on, just as simply, using a locking mechanism. In the same way, all parts can be removed for maintenance.

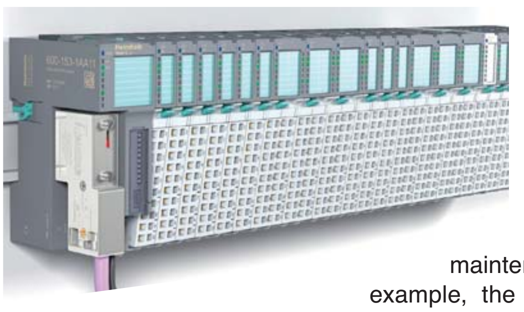


Figure 1: Scalable I/O devices with analog and digital ports

Figure 2: The three-part design allows an easy configuration and supports the hot-plug of modules

Handling is aided further by the ergonomic form of the housing. Despite their compact, space-saving dimensions, all system components are mechanically stable and designed for use in industrial environments. Prerequisite is a special plastic that has been used successfully in other products. The I/O family is scalable. Modules are available for two, four, eight and even 16 channels, a granularity that ensures the minimum of unused channels. This in turn reduces the price per channel. In addition each module is fitted with a freely usable auxiliary clamp, that can be used flexibly, for instance for additional voltage, screen or earth.

Last but not least, the design facilitates a clear and unambiguous labeling of the channels using description strips that can be printed on a laser printer. Even in assembled state these are easily visible and thus ensure an unambiguous allocation of the terminal clamp to the corresponding channel LED.

All devices can be configured easily, leading to rapid commissioning. A separate factory-coding of the modules avoids errors due to mistake or mix-ups. The hot-plug capability is one of the system's most convincing features: It means that individual modules can be removed from the overall system while leaving the remaining parts running. Any electronic module that fails is easily replaced and thus immediately available for usage, reducing downtime to a minimum.

At the same time, the capability to partially shutdown the system simplifies root-cause testing in the case of faults. The hot-plug capabilities of the system also mean that flexibly adapting to changed requirements is trouble-free. Using the corresponding separation modules, security functions can be implemented. In the case of malfunction, the corresponding power circuit is simply switched off. This continuous-development process ensures that we can always respond to customer inquiries and new, industry-specific requirements. Thus, our engineers are already concentrating on the integration of further I/O functions, such as communication modules, counters and pulse-width-modulation (PWM). ◀

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Combining energy efficiency and dynamic hydraulics

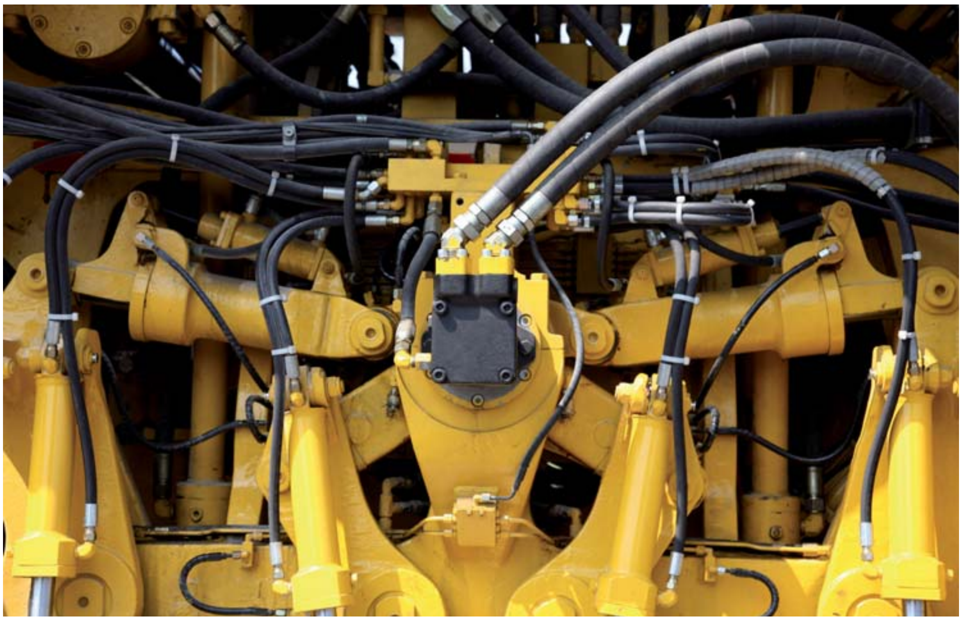
Christian Wendt

Author
Christian Wendt
Head of the Technological Control Systems group

Eckelmann AG
Berliner Str. 161
65205 Wiesbaden
Germany
info@eckelmann.de

Link
www.eckelmann.de

Abstract
The E-HyCON hydraulic drive with two to four CAN interfaces closes a gap in automation systems: It drives highly dynamic multiple axis applications with control cycles of less than 1 ms, while simultaneously controlling pump power with a variable speed drive and using predictive strategies to anticipate demand. The proportion of wasted idle power can thus be significantly reduced for many industrial hydraulic applications, especially where there is a cyclical pattern of transient maximal current requirements.



In an article on trends in fluid technology, Prof. Murrenhoff emphasized that "a huge challenge for the growth of the hydraulics industry will be improving energy efficiency." The further development of individual components, however, will not be a sufficient step, instead it will be far more important to consider the system as a whole. Drive and control technology for hydraulic applications can make an important contribution in this regard. In fact, most hydraulic applications today have a significant gap in automation and signals processing between the pump drive and the process. Depending on the individual load profile, this can lead to considerable power losses. Blanket statements of the saving potential are not possible but experts assume between 50% and 70% depending on the application.

Driving the pump motor based on demand is usually impossible, because the core component of the pumping unit is a constant speed pump that cannot be electronically controlled. A hydraulic loop that "regulates" itself using a pressure-limiting valve is employed in a traditional pumping unit, but with insufficient effect. Once a piston has reached its end position, the pump continues to deliver fluid up to the maximum set pressure. Then the pressure-limiting valve opens and the pump discharges into the tank. The unused volumetric flow Q leads to considerable performance losses in many hydraulic applications.

Particularly during cyclic pauses, with partial loads or in stand-by mode, the required pump power is significantly lower and a traditional hydraulic controller using a pressure-limiting valve is extremely inefficient. Hardly any hydraulic system permanently requires maximum power. From here, a control strategy can be derived that provides pump power as needed, and the result would be an increase in volumetric efficiency and therefore also the total efficiency. The proportion of unnecessary idle power would be reduced.

Demand-controlled pump power

There are currently two major approaches to demand-controlled pump power being explored: power or flow rate controlled axial piston pumps, with either fixed speed or variable speed drives. The fixed speed approach usually involves pumps with controllers tailored to the specific application.

Variable speed pumps on the other hand, have ▷

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Conclusion

The described solution for comprehensive, intelligent automation of hydraulic applications is independent from hydraulic pump manufacturer or drive manufacturer, because it takes over pressure and volumetric flow rate regulation from the machinery host controller. In contrast to the solutions from competitors that implement these functions directly using a frequency converter, this offers a machinery or facility designer more freedom and makes it easier to retrofit it to existing facilities.

The energy efficiency functions are more than just an add-on for controlling hydraulic pumping unit, they bring together the things that from a comprehensive, automation technological standpoint belong together: Hydraulic pumping unit and axis controller.

Just as in human beings, movements and facial expressions are the perfectly coordinated interplay of brain, nerves, blood and muscles, hydraulic cylinders, the muscles of a machine, must be directed and controlled in coordination and supplied with the precise level of energy required. Though this biological comparison may be awkward, the integrated signal processing by brain and nervous system is a vital principle of life to which technology owes many innovations.

References

Prof. Dr.-Ing. Hubertus Murrenhoff (RWTH Aachen): Trends in fluid technology [in June 2011 issue of the "fluid" German magazine] www.mi-verlag.de

Figure 1: The E-HyCON hydraulic drive by Eckelmann with I/O modules and safety module

several key advantages: not only can better value constant pumps be used; but it is also possible to make a more intelligent and more integrated connection between hydraulic power unit and axis controller. The control technology can do far more than just react to hydraulic system parameters like volumetric flow rate or pressure, it can use predictive control strategies to actively match pump power to requirements. The goal of this is to deliver only as much volumetric flow, pressure and therefore also energy from the pressure station, that is actually required for the movement of the axis.

Probably in the next few years the concept of using variable speed pump drives will prevail because of the insight that much greater improvements in energy efficiency can be achieved by considering a hydraulic application as a complete system, that is, from a perspective of control technology that comprises both hydraulic pumping unit and axis controller. In contrast, using pressure or flow-rate controlled pumps means using individual components with the lack of an intelligent higher-level system.

Controller concept

Technically, this can be realized with an integrated system, responsible for drives, pumping unit and axis controller. The E-HyCON controller was specially conceived for hydraulic applications and has the ideal prerequisites. It controls demanding multiple axis applications (up to 64 axes) with a control cycle of less than 1 ms and simultaneously matches flow rate and pressure exactly to requirements. The hydraulic algorithms that have been implemented can take into account special characteristics of different equipment and compensate for nonlinearities, for example. Depending on operational state, the software reacts to slower movements or pauses (stand-by) by reducing speed. If, on the other hand, a fast and sustained movement is expected, the controller can anticipate this, accelerating the pump motor ahead of time to serve the increased demand.

Figure 2: Hydraulic pumping unit in a steel mill

Where multiple pumps are being driven in parallel, on and off sequences can be staggered. The controller dynamically controls the delivery of whatever flow rate is required. This is achieved using variable speed pump drives. It can control the frequency converter.

Adaptive regulation with variable speed pump drives has the energy-saving side-effect of generating less heat and so also reduces the power needed for cooling. Cooling systems can in many cases be downsized.

The controller also monitors and controls the circulating pump in the filtered cooling circuit. As well as the hydraulic-specific monitoring functions for temperature, oil level and filter, it is also well-suited to condition-monitoring of the axis controller.

Experience and simulation

Our long-time experience in automating demanding hydraulic applications has fed into the development of the hydraulic controller. Machine builders can profit from this know-how, in the form of an extensive library of controller building blocks ▷

and technological functions. The application software can be programmed with Codesys in conformation with IEC 611131-3. We advise and assist designers of machinery and facilities with hardware configuration, software programming and successfully bringing systems into service. In contrast with traditional product offerings, we take the responsibility for a complete solution.

Every hydraulic application has unique requirements. In order to find the right control strategy and optimize energy efficient, we also employ modern simulation methods using Matlab/Simulink that yield valuable information starting from the design phase. It also allows designers to predict the system's operational behavior and then compare actual and simulated values so that errors can be recognized as soon as possible.

HMI-design and safety functions

With HMI-design finished visualization building blocks can be accessed. In the accompanying E-Tools VIS visualization package, there are special symbols available for the creation of animated hydraulic schematics. A variety of hydraulic applications with intuitive and appealing user interfaces can be created with little effort.

With its integrated webserver, the hydraulic controller is dynamically accessible with a web browser using HTML, as well as other protocols, for example, XML. This makes it possible to monitor a facility with a PC, a tablet, or a smartphone.

Additionally, the hydraulic control unit provides safety functions with its safety module and is well equipped for the safety requirements demanded by the new Machinery Directive. ◀

A panel PC instead of controls and instruments

Joachim Nakat and Stephan Mark

Authors
Joachim Nakat
Janz Tec AG
Im Dörener Feld 8
33100 Paderborn
(Germany)
joachim.nakat@janztec.com

Stephan Mark
Trepel Airport Equipment GmbH
Hochhäuser Str. 18
97941 Tauberbischofsheim
(Germany)
stephan.mark@mafi.de

Links
www.janztec.com
www.trepel.com

Abstract
Trepel, the leading manufacturer in the cargo high loader market, has introduced its product line, the Challenger tractor. These vehicles are able to handle pushback, maintenance towing and repositioning of any commercial aircraft, up to the Airbus A380, and almost every military airplane. The Challenger fleet is designed to perform under tough working conditions as well as extreme climatic conditions. The ballasted version of Challenger 700 can handle weights up to 600 t. Instead of usual controls and instruments, the dashboard is equipped with panel-PC from Janz Tec. This is the main control center of the tractor and the display of all relevant data provided by the internal CAN network.

The lead figure shows the ballasted version of a Challenger 700 with a weight of 70 t and an Airbus A380 ready to be pushed towards its launch-position. To offer the customers a maximum of performance these tractors are equipped with a diesel-engine (330 kW) and a ZF power shift transmission (6 gears forward, 3 gears backward). Another big benefit is the agility because of the four different steering-modes (front-axle-, rear-axle-, crab- and all-wheel-steering). For comfortable driving conditions a modern hydro-pneumatic front axle suspension system is installed.

Two control units

Two programmable mobile controllers are installed at different places. One is located in the driver´s cab-in, the other in the middle of the tractor next to the main hydraulic system. Six CANopen devices are used to get the information from the binary switches and the analog sensors. They also drive the hydraulic valves, which are spread all over the machine. Some programmable μPLC´s are working with CAN layer-2 (they are used for add-ons) communication system.

The diesel-engine and the transmission use for data exchange a CAN network running the SAE J1939 protocol. As you can imagine it is not easy to recover a huge vehicle with a weight up to 70 t. Therefore, the system has been designed this way to ensure the utmost reliability.

The devices are connected to six different CAN ▷

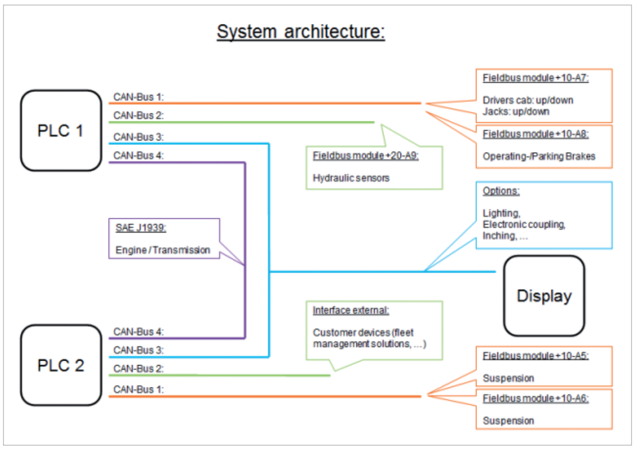


Figure 1: Network architecture with two PLCs and several CAN networks

networks in order of their function and because of the different protocols used. Another reason is to maximize the immunity of the system against failures. Even if one CAN network breaks down, all the others keep on working and the tractor can be operated with a minimum of limitations. This, and the fact that there are some sorts of other emergency strategies, is very important for a highly reliable machine.

One CAN network is reserved just for customer devices such as fleet management solutions etc. Here almost every customer´s requirement can be fulfilled, no matter if it is CANopen, SAE J1939 or CAN layer-2 protocols. Different bit-rates are possible as well. Another CAN segment is used to build the 'backbone' for data exchange between all single devices. Every PLC, and of course the panel PC is connected to this backbone network. Each device transmits its set of data over a CAN layer-2 protocol. Needless to say it has access to all messages from the others.

One job of the two main PLC´s is to work as a CAN bridge/gateway. They receive the SAE J1939 messages from the power train CAN (engine and transmission) and make all necessary information accessible via the CAN 'backbone' network.

Display of the dashboard

The display is mounted in the center of the dashboard (behind the steering wheel).

It is a non-touch-version to avoid fingerprints on the screen and improve the readability. Its control-buttons (up/down, escape/enter) are installed separately to make them more reachable.

The display used in this application is basically an emVIEW-6 from Janz Tec. It offers all functions needed, such as a compact ARM-based system with small footprint and low energy consumption rates. Additionally the system can be used under rough working conditions because it also offers an extended temperature range. All the interfaces, which are needed, are included as well:

- One CAN interface (busmaster)
- Two 10/100-Mbit/s Ethernet ports
- Two USB V2.0 ports
- One serial EIA-232 interface

The device comes with all software support needed. It is equipped with Windows CE and Codesys, a soft PLC compliant to IEC 61131-3.

But the real important part is that the panel PC was customized to the very special requirements of Trepel. It has got a unique design and is now equipped with a daylight readable display. So the operators can read the display at any lighting condition.

The main display of the panel PC gives all important information to the driver.

It is designed to meet the needs of the operator. Everything is located on one page to give him a good overview. Here he can find an array of indicator lights, the engine-speed, two bar graphs and a text field for error messages, etc. Starting with simple things like the status of the battery charge control and the parking brake it also shows the steering-modes, the position of the axles, the actual gear and some additional information from the gearbox. The variable brightness makes it very easy to switch between day and night conditions.

Service and maintenance

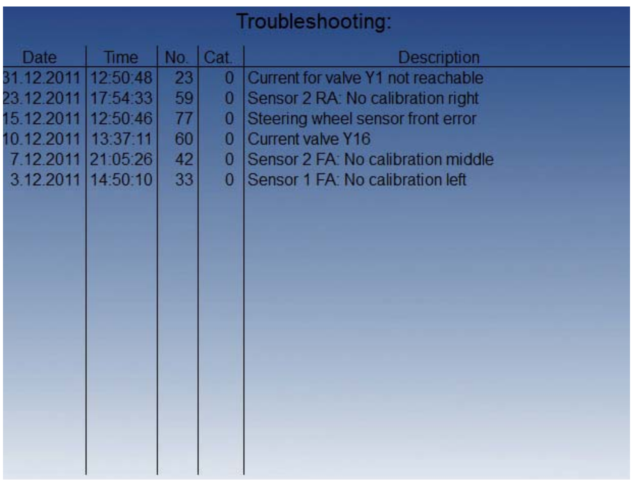
Normally an external device will be plugged to a special diagnostic connector to give service personal the opportunity to check for error messages and other additional information about the status of the vehicle. One of the great advantages of the system configuration is that all these functions are integrated in the display. So there is no need to use additional equipment or any other computer device to check for errors and other diagnostic data of the vehicle. To make the system more service-friendly there are many different pages, which provide all available information.

For example about the engine, the power shift transmission, the steering system. Furthermore there is an error logbook, a page for service issues, visualizations of the fieldbus-modules, parameter, calibration, etc.

Usually the service engineer doesn´t need a laptop to do his maintenance job, neither for troubleshooting. It only needs a few clicks to change the language or to adjust the date and time.

On the engine´s page there are several values displayed, such as the engine´s speed, the fuel consumption and the percentage load. The coolant-, intake-, and fuel temperatures are also shown. Another advantage is that it indicates all existing errors. It allows reading out the codes and how often the errors occurred very easy. In the past you had to decode the blinking-code of a diagnostic lamp to get the same result.

The transmission´s visualization behaves like the engine page. It reports different oil temperatures and rotation speeds, etc. The built-in error logbook saves every failure of the system on a flash card. Each entry ▷



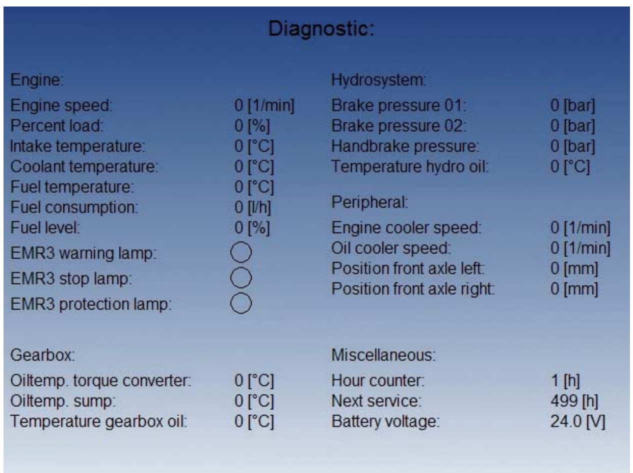


Figure 3: Diagnostic and trouble-shooting

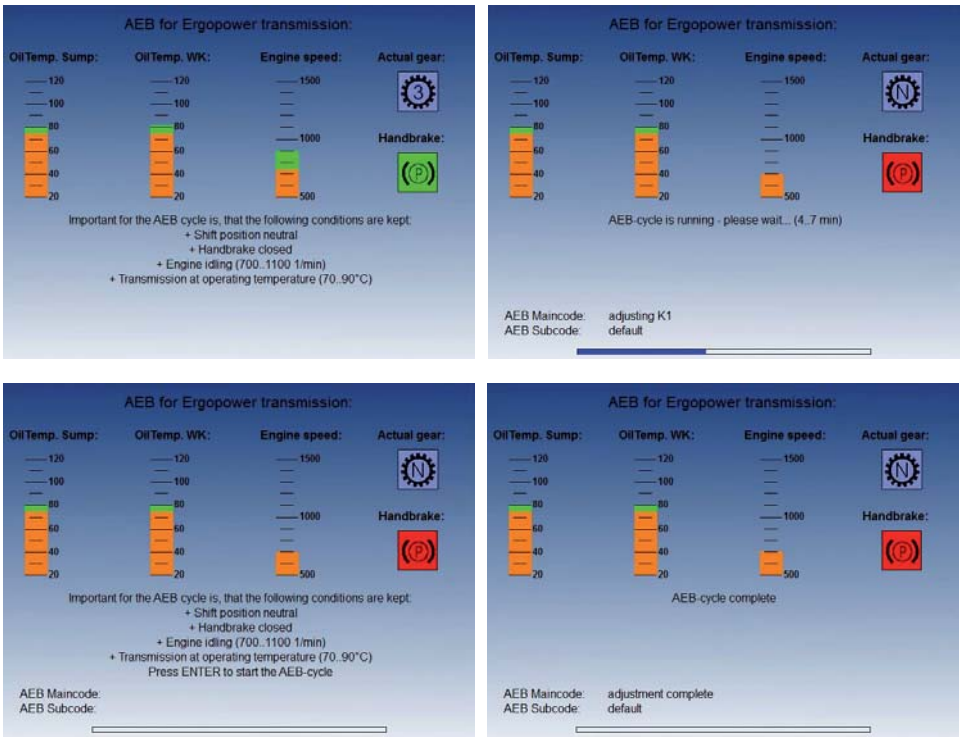


Figure 4: AEB-Start (service example)

gets a timestamp. Additionally a snap-shot from important system values is stored as well. This is helpful for later diagnostics. The entries can be listed chronologically to get a quick overview.

To get a deeper look into the electronic steering system there are separate pages with all the information. From just checking some settings up to calibrating a new angle sensor - everything is possible over the CAN bus.

To show you the service features of the display, we will take one maintenance procedure of the gearbox-controller as an example. This function is called AEB (automatic determination of filling parameters).At the initial startup of the transmission and after each periodic service a special cycle has to be performed. One way to do this is to buy special equipment and connect it to the gearbox-controller. The other and much easier and faster way is to use the panel PC. You just have to select the AEB-mode on the transmission´s page and enter the password to reach the visualization.

After you are in the AEB-mode the characteristic curve of the gearbox cooling-fan is moved to higher temperatures. This is helpful because the transmission´s oil has to be heated up to a certain value. The display shows any information the operator needs (temperatures, engine speed, actual gear and the status of the parking brake). It also tells the service engineer what starting conditions are necessary and when they are met.

Then the cycle can be started – just by pressing the enter-button. This information is transmitted via the CAN bus to one of the PLCs. There it is translated into the SAE J1939 protocol and transmitted to the gearbox-controller. Once the cycle is running its status is displayed to give the operator a direct feedback of the process. Finally the system shows if the process ended successfully or has been aborted by an error and which kind of error occurred.

For a quick and comfortable I/O-check the system provides a separate visualization to display which input- or output-channel is switched on or off. The values of the analogue inputs are shown as well as their pendants, the PWM-outputs.

However, these pages can be used for trouble shooting of the CAN bus as well. They show some CANopen-specific data like the node state of each slave. For example:

- Status 03 – The configuration of the device is actually running.
- Status 05 – The device is normally running.
- Status 97 – The device is optional and didn't answer the SDO-request of the master.
- Status 98 – A wrong device was installed.

Last but not least it is displayed if the device is online or not.

This information helps to locate where the possible problem is and decreases the machine´s downtime. ◀

Conclusion

There are a lot of reasons to use CAN networks for vehicles like Challenger:

- Modular construction
- Reduced wiring complexity
- Faster installation
- Easy diagnostic (self-test)
- Open for add-ons
- Fail-safe
- etc.

The fact that CAN protocol automatically detects transmission errors and retransmits the faulty messages prevent errors in the system, too.

"We think, that CAN´s success story will continue!"

The authors

Partial deactivation of CAN nodes

Fritz Burkhardt

Author
Fritz Burkhardt
STMicroelectronics

Link
www.st.com

Standardization

As mentioned in the article, car manufacturers have decided to bring partial networking into volume production. However, this can only be realized if the required transceiver features can be standardized so that the semiconductor suppliers can develop and industrialize the respective devices. For this purpose, the Switch (Selective Wakeable Interoperable Transceiver CAN High-speed) group has been created to prepare a specification to be submitted for international standardization. The submitted document is currently being discussed by the International Standardization Organization to define a supplement for ISO 11898 (Road Vehicles – Controller Area Network CAN). STMicroelectronics is an active contributor in the definition of this functionality within the mentioned committees and is working intensively on the implementation of suitable transceivers.

Electronics is a major driver for innovation in modern vehicles. Whereas numerous power train and safety features remain barely visible for the end user, such cars offer countless functions aiming to increase convenience, comfort and assistance for the driver and passengers. As a result the number of electronic control units (ECUs) inside the car has increased dramatically. In high-end vehicles up to 100 modules are installed. They are interconnected by bus systems to facilitate communication among them.

Legal regulations for CO_2 emissions require reduction of energy absorption wherever possible. In the past, fuel consumption of the combustion engine and weight reduction was the main focus area to achieve these requirements. Today, the overall power consumption of the car electronics is no longer negligible. Carmakers and electronic suppliers make significant efforts to collect every mA to further reduce energy input to the car.

The use of electronic components with minimum quiescent current is an obvious step but can be considered state-of-the-art. But analyzing the electronics landscape in modern vehicles quickly raises several questions. Are the functions offered by the many control units really required at all times and in every driving situation? Is the continuous current drain of these modules really justified? Obviously, the answer is no for convenience functions such as seat electronics, trailer- or tailgate control units because these functions will only rarely be operated or they are not required at all times. Additional examples include door control units, auxiliary heating, sunroofs and rear-view cameras.

All these modules are commonly integrated in CAN networks and consume full operating current even if no specific action is requested from the module. The ongoing communication on the CAN network requires the unit to decode every message and scan for tasks to be carried out.

In consumer electronics and mobile communication, the use of standby modes is well known and considered state-of-the-art. In the car, standby modes are used only when the vehicle is parked. The entire communication network is activated as soon as the car is in use and individual CAN nodes cannot remain in standby while the rest of the bus is communicating.

A new network concept is needed which allows single ECUs or groups of modules to be in stand-by ▷

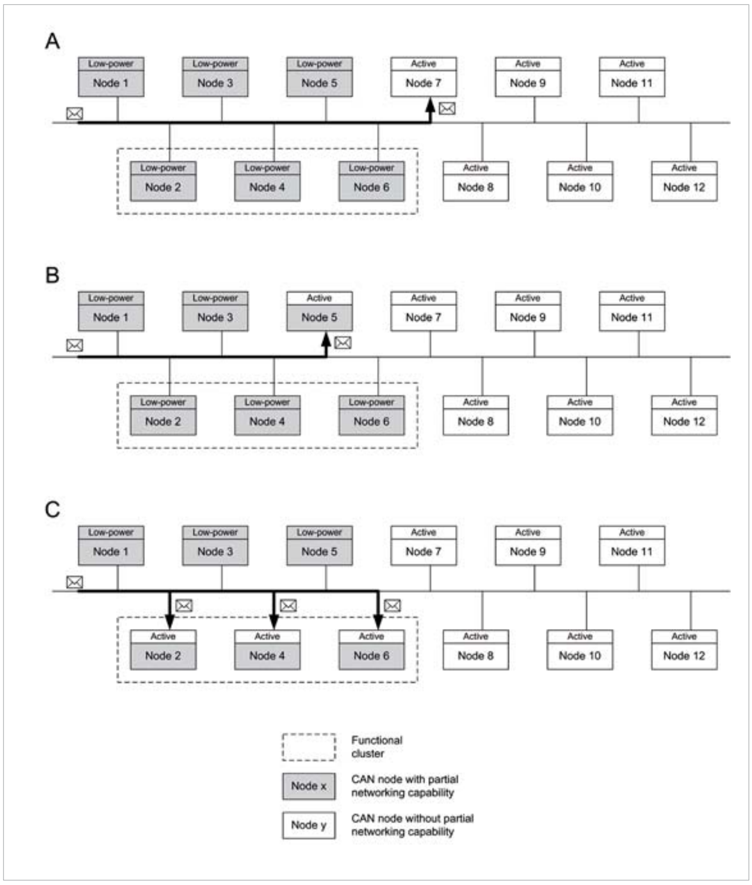


Figure 1: transmission of messages in a CAN network adopting 'partial networking'

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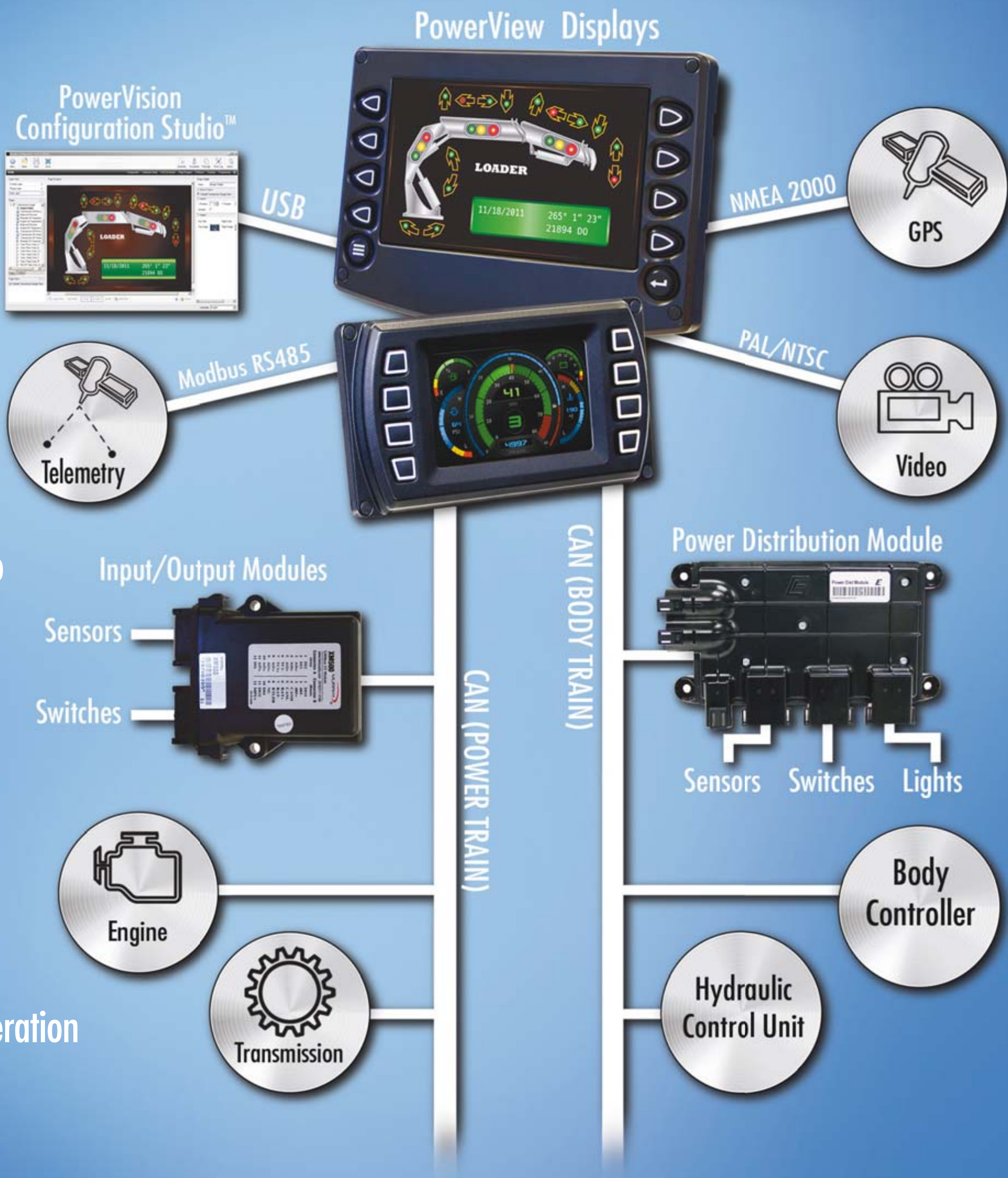

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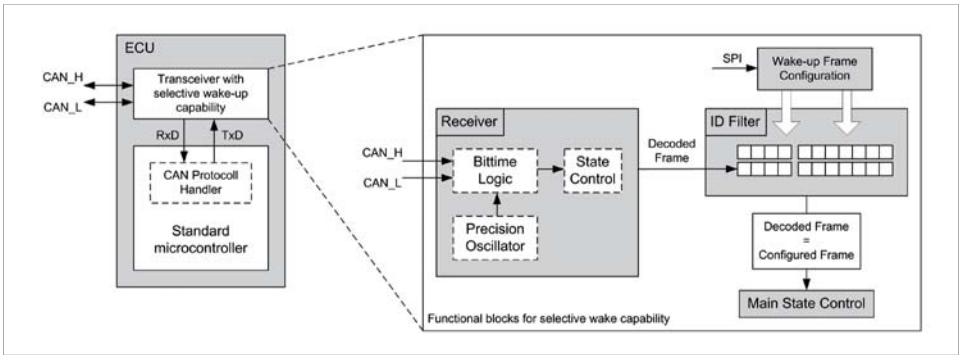


Figure 2: ECU with partial networking transceiver

Product announcement
The L99PM72PXP Power Management System IC is the first SBC (System Basis Chip) supporting the partial networking function. It is based on the L99PM62GXP which is already in production for several years and is hardware and software compatible with this device. It is developed by STMicroelectronics in close co-operation and co-ordination with a major German car manufacturer. Samples are already in evaluation and volume production is planned for Q4, 2012. STMicroelectronics thus complements its family of Power Management System ICs with a device leveraging existing IPs combined to create application-specific components.

while other nodes are communicating on the bus. In addition it is necessary to wake up individual nodes by means of a dedicated and pre-defined message on the bus when a particular function is needed. This new mode of operation is called Partial Networking and requires transceivers with selective wake-up capability. These transceivers are able to receive and decode CAN messages autonomously without the help of the micro-controller (Figure 1 shows the transmission of messages in a CAN network which contains nodes supporting partial networking).

In scenario A the bus is active and a message is addressed to node 7. Nodes 7 to 12 are active due to the ongoing bus communication while nodes 1 to 6 remain in low-power mode because they were not addressed by a selective wake-up message.

In case B a selective wake-up message is addressed to node 5. This node recognizes the wake-up request and enters active mode. Nodes 7 to 12 remain also active due to the ongoing bus communication while nodes 1 to 4 and 6 remain in low-power mode.

In scenario C a selective wake-up message is addressed to a functional cluster consisting of nodes 2, 4 and 6 causing theses modules to enter active mode. This is the case if a user request (e.g. door unlock) requires several independent modules (e.g. front and rear door modules) to perform a particular action (unlock all doors).

The strength of conventional transceivers is the capability to translate bus-level signals with full fidelity while maintaining immunity against external noise, bus interferences and electrostatic surge, which are common in automotive environments. Having only very basic logic functions for detecting bus errors, they are activated by every level transition of the bus or by simple patterns of the bus signal. This, in turn, precludes capturing and evaluating any incoming messages because this is traditionally the task of the MCU's on-board CAN controller which has a precise reference clock (crystal oscillator) required to receive and evaluate the incoming CAN frame.

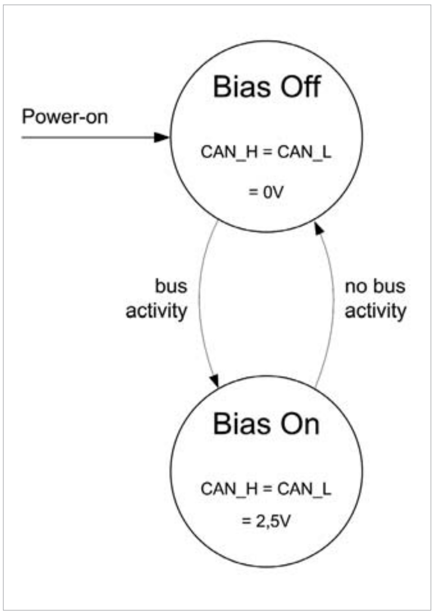


Figure 3: Automatic Voltage Biasing (operating principle)

CAN transceivers capable to detect specific wake-up messages therefore need a highly precise internal reference clock in order to reliably capture and decode the incoming bit stream and a decoder to extract and evaluate the data content. Obviously, the reference clock requires high precision and must be stable over the entire automotive temperature range.

The required oscillator precision is of course dependent on the maximum bit rate foreseen for the network. But in reality the conditions inside the car are far from being ideal. Complex network topologies, long cables and a noisy environment introduce significant disturbances to the CAN signals. The following factors have to be considered in order to ensure reliable functionality in a real vehicle:

- Sender clock tolerance
- Signal propagation delay
- Electromagnetic Interference (Jitter)
- Ringing after signal level transitions

For a bitrate of 500 kbit/s and a sender tolerance of 0,4%, the oscillator must provide a precision of <<1% over the entire temperature range and the operating life of the component.

Oscillator concept in partial-netwoking

The oscillator concept used in partial-networking transceivers therefore plays a primary role and represents the main challenge for the development of these devices.

In conventional CAN networks according to ISO 11898-5 the bus is either active (ongoing communication) or in low-power mode (bus silent). Consequently, each node is sent into low-power mode by its host microcontroller as soon as communication has ended. As soon as communication on the bus is restarted, the transceivers activate the nodes by waking up the system microcontroller.

The Biasing of the bus lines CAN_H and CAN_L in this case is determined by the operating mode of the transceivers (active or low-power).

In case of partial networking, the situation is different. Some bus nodes are communicating while others are in low-power mode. Obviously, the powered down nodes must not influence the biasing of the active bus. Therefore, a mechanism is needed which determines the bus state and automatically turns on and off the biasing of the 'sleeping' transceiver.

This mechanism is called 'Automatic Voltage Biasing'. The operating principle is depicted in Figure 3. Communication on the bus is detected if a dominant-recessive-dominant sequence, which follows specific timing requirements is present on the bus. In this case the Biasing is turned on (CAN_H and CAN_L biased to 2,5 V).

If no bus activity is detected for a specified time, the Biasing is turned off automatically (CAN_H and CAN_L biased towards 0 V) assuming that communication on the entire network has stopped. ◀

Power saving in CAN applications

Magnus-Maria Hell and Ursula Kelling

Authors
Magnus-Maria Hell
magnus-maria.hell@infineon.com

Ursula Kelling
ursula.kelling@infineon.com

Infineon technologies
Am Campeon 1-12
85579 Neubiberg
(Germany)

Link
www.infineon.com

Abstract
During the last years, the discussion about power saving had and has different aspects. One of them has been to save power in CAN applications. The mechanisms, which can be used either on physical layer or on the micro-controller, will be discussed within the article.

In a normal CAN network, all nodes are permanently active when the CAN communication is running, independently if the ECU (electronic control unit) is used or not. However, many applications are not used all the time, and these ECUs can be switched off to reduce the power consumption. A solution for such a realization must fulfill the following criteria's

- No negative impact on the physical bus (no disturbance)
- Can be awake with a dedicated CAN data/remote frame
- Low-current consumption

In addition, three different situations must be covered from this solution. In normal CAN communication, in start-up phase of the car, and in parking cars:

- In normal CAN communication, not needed ECUs can be set into a special sleep-mode. All other CAN nodes can communicate and will be not disturbed from the deactivated ECUs. With a dedicated wake-up frame, one or more ECUs can be awaked with a short time-delay.
- During the start-up of the CAN network, all ECUs ramp-up and together, they will consume a lot of current. This is not necessary and with the new approach, only the needed ECUs should be ramped-up. All other nodes changes from sleep mode in a bus observation mode. After the successful ramp-up, the other nodes can be added one by one into the communication, if necessary.
- If you park a car, a very low-current consumption is required to unload the battery. However, if for example the radio is on, all CAN ECUs located on this CAN network will stay active and consume a lot of current. With the new solution, only the necessary ECUs are active (for example wheel to control the radio and the radio itself) and all other nodes a sleeping or shut off. This reduces the current consumption dramatically.

Two different solutions cover the power saving criteria. One, called partial networking is based on a modification of the transceiver and the other ones called pretended networking, which is realized in the micro-controller.

In the partial networking approach, the wake-up frame detection unit is implemented in the high-speed CAN transceiver. This new unit compliant to ISO 11898-6 (under development) contains

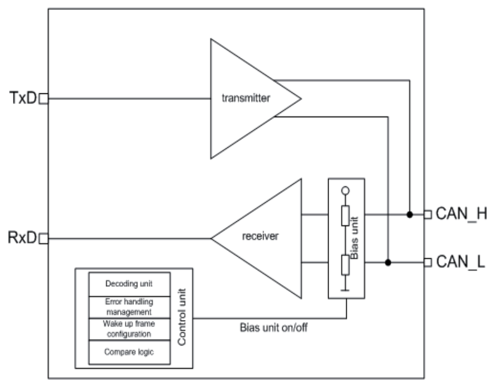
- A high-precision oscillator
- A CAN message decoding unit
- An error-handling management
- A wake-up frame (WUF) configuration
- A compare unit
-

During selective wake mode, this transceiver is active and monitors the CAN communication like a watchdog. If a dedicated can frame is observed, the transceiver wakes-up the ECU. These kinds of transceivers have now two modes in the so-called low-power mode:

- Sleep-mode
- Selective wake-up mode

In sleep-mode, the current consumption is reduced to a minimum; all functions in the ECU are disabled. Every message on the bus wakes-up the transceiver and the ECU. In selective wake-up mode, the current consumption is also low, but the wake-up frame (WUF) detection unit is active, and monitors the bus. All other functions are disabled. With the dedicated WUF, the transceiver and the ECU will be woken-up.

The advantage from this approach is a very low-current consumption in low-power mode. The disadvantage is the fact, that only one dedicated WUF awakes the ECU. In addition, the long ramp-up time is a disadvantage for this system. A first implementation from Infineon can be found on the TLE9267QX. Pretended networking describes an approach developed in Autosar. Pretended networking in combination with ECU degradation allows safing power on micro-controller basis. What do these concepts mean? First of all, they integrate well-known power-saving approaches back into Autosar, possibly still used by the industrial world. ▷



ECU degradation allows using the HALT mode, also known as IDLE for CPUs. In case of no task is running, the CPU is no longer doing NOPs, but will go to IDLE and therefore the CPU is no longer clocked. As soon as the first interrupt is executed, the CPU is active again. This is already the first power saving step. The next power saving step, is that all modules not used in a low power operation mode, will be shut off, therefore power can be saved. Now going for pretended networking, the communication modules will run with a reduced message catalogue and reduced amount of interrupt sources to allow longer sleeping times of the CPU. These well-known power-saving measures, initially used only during the park situation of a car, will know be used during driving. Dependent on the existing software stacks, these measures will be well known, or can be integrated as long as the software is able to cope with shut off modules or CPU in idle. These measures are sophisticated, as for example they are only existing on devices as the C167 and have been part of newer devices ever since. An additional measure, which needs more software influence is the changing of the clock for a device.

In case the device is not prepared for such a measure, all communications have to be stopped, the bitrates have to be adjusted, and then all communications can be restarted. If microcontrollers are prepared for these measures, than a central clock switch will exist, not touching any communication. If all measures are combined, saving of 50 to 60% of the ECUs power consumption can be achieved. Even though this might sound neglectable, in times where every mA counts, these measures will help to safe a sufficient amount of power. ◀

Summary

The CAN transceiver as well as the micro-controller can help to safe power. For all applications, which have wake-up times greater than 100 ms or 200 ms for safety applications, it is possible to shut-off the ECU via the CAN transceiver as long as the network is able to handle this. For all others pretended networking in combination with ECU degradation will help to safe as much power as possible. Many of the features already exist in today's micro-controllers, as for example the XC2000/XE166 or Audo Max family, for the Aurix family even more is to come.

Related articles

Partial networking reduces CO_2 emissions (in CAN Newsletter 4/2011, page 8/10)

Partial networking for conventional and electric vehicles

Bernd Elend and Steffen Müller

Authors

Bernd Elend
bernd.elend@nxp.com

Steffen Müller
st.mueller@nxp.com

NXP Semiconductors
Germany

Link
www.nxp.com

For all types of vehicles (conventional with combustion, electric, and hybid engines), energy savings are important but driven by different aspects. In the conventional car, reductions in CO_2 emissions can be managed by reducing standby power through switching off electronic-control units not in use, which has environmental and tax advantages. Figure 1 shows optional units for this. However, in the electrical vehicles (EV) the operation range is increased by the efficient implementation of its energy management system. This controls the energy flow in the typical system states of the EV (driving, charging, and parked) and state transition.

Energy savings in CAN networks can be realized by "Partial networking" (PN) that introduces the new function "selective wake-up." PN has been proposed by the Switch group, a group of carmakers and semiconductor suppliers, and is now on its way to become an extension to ISO 11898. Compared to existing products that conform to ISO 11898-5, additional functionality in the transceiver is needed to detect the wake-up message.

What are trends in in-vehicle networking when we compare an EV to a conventional vehicle? To what extent can paradigms be sustained, which have been formed based on conventional vehicles?

The following summarizes the system challenges of an EV that have an impact on in-vehicle networking:

- Lifetime and safety – introduction of new safety-relevant embedded systems
- System complexity – new energy sources and new power trains result in new network demands
- Robustness – harsh automotive environment, fast transients in power electronics in electric drive
- Isolation towards human interface – high voltages (far above 60 V_{DC}) across the in-vehicle network

The networks of conventional cars shut down when parked. For the EV, the battery charging time adds to the vehicle operation time. Furthermore, EVs have to be alert for critical situations such as failures in the system or in the high-voltage battery, for example, in case of a car crash. Thus the EV never sleeps completely and a minimum level of communication has to be and will be active almost around the clock.

As mentioned, some functions are always active (e.g. battery monitoring) and create bus traffic. This keeps modules in ISO 11898-5 CAN networks active even when these modules do not contribute to the minimum set of required functions. A mechanism is needed that allows functions to be switched on or off while other functions remain active and exchange data via the network. PN provides the necessary feature for networks to switch off modules to save their standby current and allows these to be quickly reactivated when needed.

Paradigm change in networking from conventional car to EV:

- Safety aspects dominate architecture and network choice (separation of voltage domains).
- Control network becomes an important means of energy management in the vehicle.
- Parts of the control network are always active.

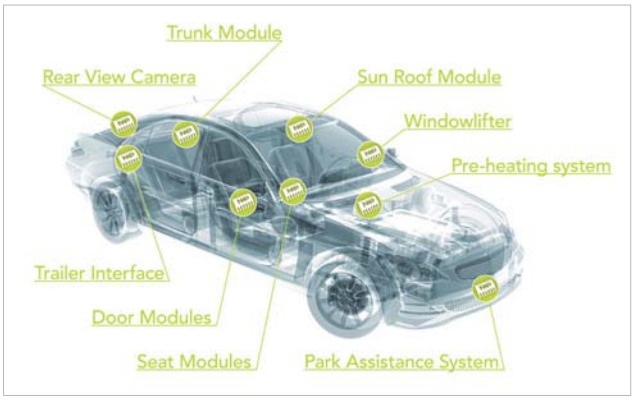


Figure 1: Units that can be temporarily switched off to save energy

Partial networking advantages

The use of PN in conventional cars is typically seen with comfort modules (functions) that can be switched off in many driving situations (see Figure 1). Moreover, PN also allows functions to be kept available when the ignition of the conventional car is turned off without draining the battery with unnecessary standby currents. Ease of implementation, robustness, and the associated costs are the major aspects to the successfully introduction the PN function in any types of cars.

To operate only a certain part of a network at a certain moment is called PN. See Figure 2, where a green box means a module is switched on, and a gray box means that a module is switched off (right car). In ISO 11898-5 CAN networks, all modules are switched on when at least two modules communicate (left car). Today, exceptions to this have been created by switching off the supply of a selected module or by using dedicated wake-up wires. These setups are hard wired and do not offer any flexibility with regard to their configuration. With PN, modules wake up by receiving a specific message sent via the network. Thus the configuration can be changed by means of a SW update.

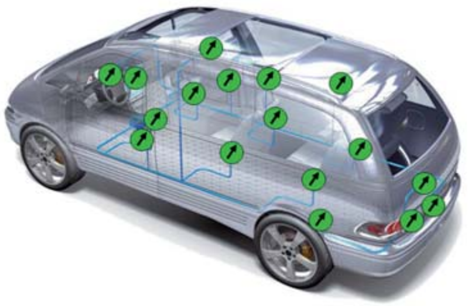
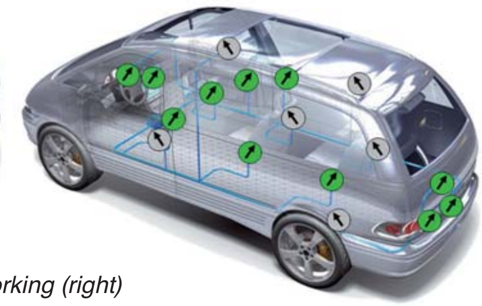



Figure 2:
Vehicle without (left) and with partial networking (right)

Partial networking transceiver architecture

In order to realize the selective wake-up function, the receiving path of a CAN protocol controller including its clock source has to be integrated into a CAN PN transceiver. Since carmakers and Tier-1 suppliers require compatibility with standard transceivers in SO14 package, there is no option to connect an external oscillator, such as a crystal or ceramic resonator, to the transceiver. Such external components would also require more supply current than an integrated oscillator and thus would be in conflict with power-saving targets. Furthermore, it would add to the cost of and space required for a printed circuit board.

If activity occurs on the network that wakes up transceivers conforming to ISO 11898-5, the PN transceiver will not signal a wake-up event on its RXD and INH pins. However, it would activate the receiver, CAN decoder, clock-source oscillator, and message filter and logic comparison. If the bus remains silent for a certain period in time (<1.2 s), these blocks will be deactivated. The wake-up event is signaled on RXD and INH in case the correct wake-up message has been received.

Overall, the major challenge for the hardware implementation of PN is finding an on-chip oscillator design with a certain accuracy, i.e. with perfect compensation for temperature, supply-voltage variation, production spread, and aging in order to comply with automotive robustness requirements, which are even higher in the harsh environment of an EV.

Modifications in the network management

Besides hardware modifications, PN implementations require changes in the network management SW. This impacts different levels of the SW architecture. The related questions have been addressed in subgroup "Efficient Energy Management" of Autosar, and PN control functionality became available with Autosar release 3.2.1.

The CAN network architecture in the vehicle as well as the HW architecture on the module level do not change when PN is intro- ▷

Initiators

German carmakers initiated the formation of the Switch (Selective Wake-able and Interoperable Transceiver in CAN High-Speed) group. Semiconductor vendors (including NXP) and further OEMs also joined this interest group. Between July and December 2010, the group developed a draft for the extension of ISO 11898 and introduced a selective wake-up function. In short, a valid wake-up message is detected when the received ID matches a predefined CAN-ID, the received data length code matches the predefined data length code, and the received data field correlates to predefined data field content.

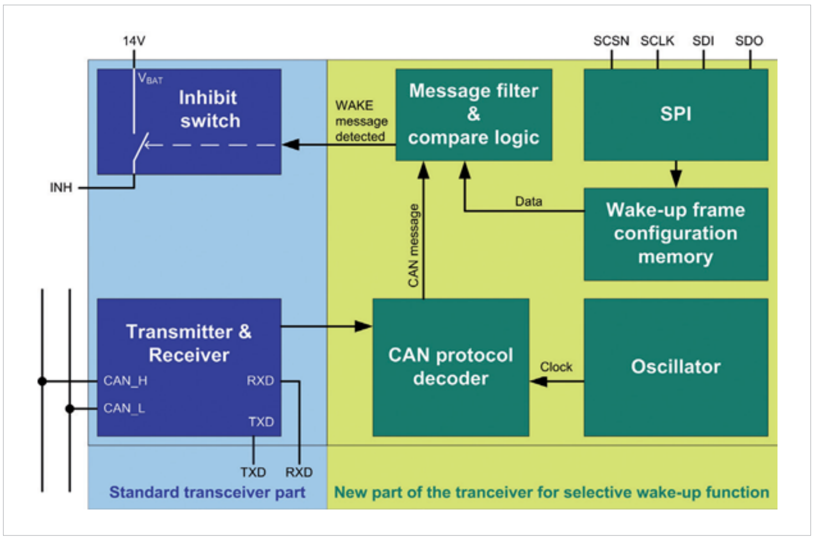


Figure 3: Example transceiver architecture of TJA1145 for partial networking

Summary

- Partial networking is an excellent means for energy management and savings
- Multiple disciplines are involved in partial networking and standardization of HW and SW
- Robustness and the accuracy of the onchip oscillator will be the key differentiators among the various PN transceivers
- EV establishes a need for extended energy management
- Partial networking contributes to all operation modes of EVs: driving, charging, and parked
- Paradigm change in networking: the shift from conventional vehicle to EV is from comfort to energy management
- Lifetime aspects in EVs are tremendously important due to embedded safety systems; parts of EV are always active

duced. The PN transceiver with its selective wake-up function is responsible for detecting the wake-up event on the network and controls the activation of the voltage regulators for the entire module. This is identical to the operation of a standard transceiver according to ISO 11898-5.

Figure 4 shows how a standard high-speed CAN transceiver such as the TJA1043 can easily be replaced on a module level by a PN transceiver such as TJA1145. However, since the configuration of the wake-up message is necessary, the PN transceiver features a SPI interface instead of having error (ERRN) and mode-control pins (STBN, EN).

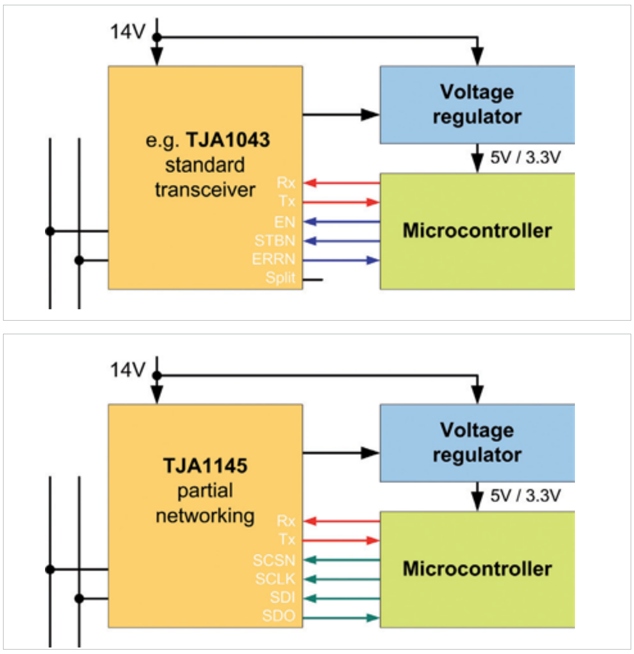


Figure 4: Module architecture for partial networking

Relevance of Partial Networking for electrical vehicles

Within the next decade, experts expect major improvements with regard to the power density of batteries. Needless to say that each “saved” watt-second directly contributes to the cruising range of an EV. PN makes an excellent contribution with a robust and reliable approach to the energy balance. The industry expects that power savings in a conventional car may add up to 100 watts. What this means for the extended cruising range depends on the EV characteristics and architecture.

In the early days of the Switch group, a decision about the basic wake-up detection mechanism was made. Two options were discussed:

- Detection by a CAN controller that is kept active while the rest of the microcontroller, in which it is nested, stops;
- Add a reduced-protocol engine to the silicon of the transceiver.

The expert community of the carmakers voted for the second option and thus limited changes to the entire system. With this, we anticipate that on the device level the above-mentioned product lifetime extension is applied to only one device, the transceiver, but not to the microcontroller, voltage regulators, capacitors, etc.

While the lifetime requirements for electronic components in EVs have not been concluded yet, a first indication from carmakers is to approximately triple the lifetime requirement. This will add to the product development lifecycle as well as to the final product cost for the device. However, it would be good if we limited the number of affected devices, and the PN draft standard does.

Robustness of in-vehicle networking is mainly immunity against injected RF energy. The Switch group has already defined dedicated EMC requirements for PN transceivers. The good news is that in the last years big steps in immunity improvement have been made and the acquired knowledge can also be applied to PN transceivers. The bad news is that experts see EVs emitting high voltage and high current transients, leading to hazardous electromagnetic fields. Thus adhering to the impulse immunity during operation in ISO 7637 might become one of the new challenges for the semiconductor suppliers.

What does robustness of PN in EVs mean in detail? Do wake-up messages have different levels of vulnerability than other messages? Yes, and the reasons are the following:

- Potential wake-up messages are received and decoded by a transceiver with an on-chip oscillator, which is likely less precise than the quartz of the attached μC that does the decoding during normal operation;
- Power consumption of the receiver is reduced to a very low value, which decreases the ability to suppress noise.

It is too early to compare robustness of “wake-up message detection in a PN transceiver” in all PN set-ups and implementation concepts, but it is clear that the critical factor is the on-chip oscillator and its resulting stability when confronted with distortions such as electromagnetic fields, ringing, sender-clock tolerances, and cranking pulses on the supply. ◀

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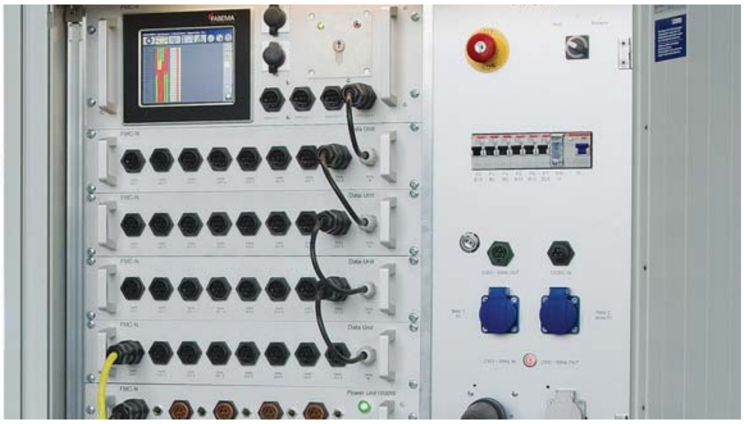

Panel PC with up to four CANopen interfaces controls traffic lights

Fabema GmbH
Hähn 10a
51515 Kürten-Biesfeld
(Germany)
The company is a market leader of mobile traffic systems and traffic safety products. Headquartered in ?? (Germany), the company develops and produces especially mobile traffic lights systems, as well as further traffic safety products for construction-site safety.

Janz Tec AG
Im Dörener Feld 8
33100 Paderborn
(Germany)
The company located in Paderborn (Germany), a long-time CiA member, manufactures board-level products and Industrial PCs with CAN and CANopen interfaces among other controllers.

Links
www.janztec.com
www.fabema.com

Abstract
Janz Tec supplies Fabema with compact Panel PCs for its mobile traffic light systems. The ARM-based device runs Windows CE operating systems. The device manufacturer also provides hardware and software modifications, so that the mobile traffic light systems can be adapted to the customers' demands.

The heart of the mobile signal system is a multi-functional controller for the mobile unit and the light-signal system fixtures. The control display in this system is the emVIEW-6T, which is used for the demonstration and simulation of the real traffic layout. All necessary traffic- related documents have to be produced fast and without any problems with this system: they are constructed in only one operating procedure with the program software provided.

The touchscreen display with a resolution of 640 x 480 pixel and a 24-bit color-depth offers the necessary easy of use, too. The demonstration and simulation of the real layouts with signals are incorporated in the control system.

Recording, documentation and printout of the data flow signal situation can be established in real-time. Also, all non-security-relevant construction parameters can be changed during operations. In addition, the configuration provides the possibility to use different construction phases in the control system, so complex reprogramming locally is no longer necessary. Neighboring signal systems or host systems can be co-ordinated with cables or by a DCF-synchronized time signal. Speeding up public transport and rescue vehicles is a standard feature of the control system.

With help of the Panel PC, all parameters can be entered locally or via remote-access maintenance, consequently reducing service costs – normally of local authorities or private road construction companies.

Furthermore, with the additional UMTS/HSPA modem the following functions can be accommodated:

- Implementation of UMTS / HSDPA / HSUPA / GPRS / EDGE to 10/100 MBit/s Ethernet
- IP at both interfaces (UMTS, Ethernet)
- Router, VPN functionality, firewall functions
- Web interface for the calibration of UMTS-, input and
- router parameters
- Update capability of overall control
- GPS support

Peter Tesch, managing director of Fabema, said: „With Janz Tec and its products we have found a powerful regional partner, who can also facilitate modifications of hardware and software directly and straightforwardly. The needed interfaces can be allocated without any problems. The custom design of the system fits well into our own Corporate Identity, so that our customers and employees can identify seamlessly with this system. The service and support from the Janz Tec's employees is phenomenal!"

The ARM-based PanelPC provides a 6,5-inch screen size. With up to four CANopen interfaces this control unit is suitable for many different applications with Windows CE operating systems 5.0 or 6.0. Using this hardware in adverse environment temperatures from -30°C to +60°C is no problem, because the ARM processor employed produces just little lost heat, allowing completely passive cooling. Display backlighting uses the newest LED (light emitting diode) technology. The manufacturer assures system availability for a minimum of eight to ten years. ◀

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- CANrepro: Replay of pre-recordedCAN message framesvia esd CAN interface
- CANscript: Python scripting tool to handle CAN messages
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the tools are free of charge on the driver CD or to be downloaded here: www.esd-electronics.com/tools

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