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CAN Newsletter

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CANopen on track – IEC 61375-3-3 voted positively

CANopen panel-PC controls Italian trams

Rail automation system speaks CANopen

Rail vehicles

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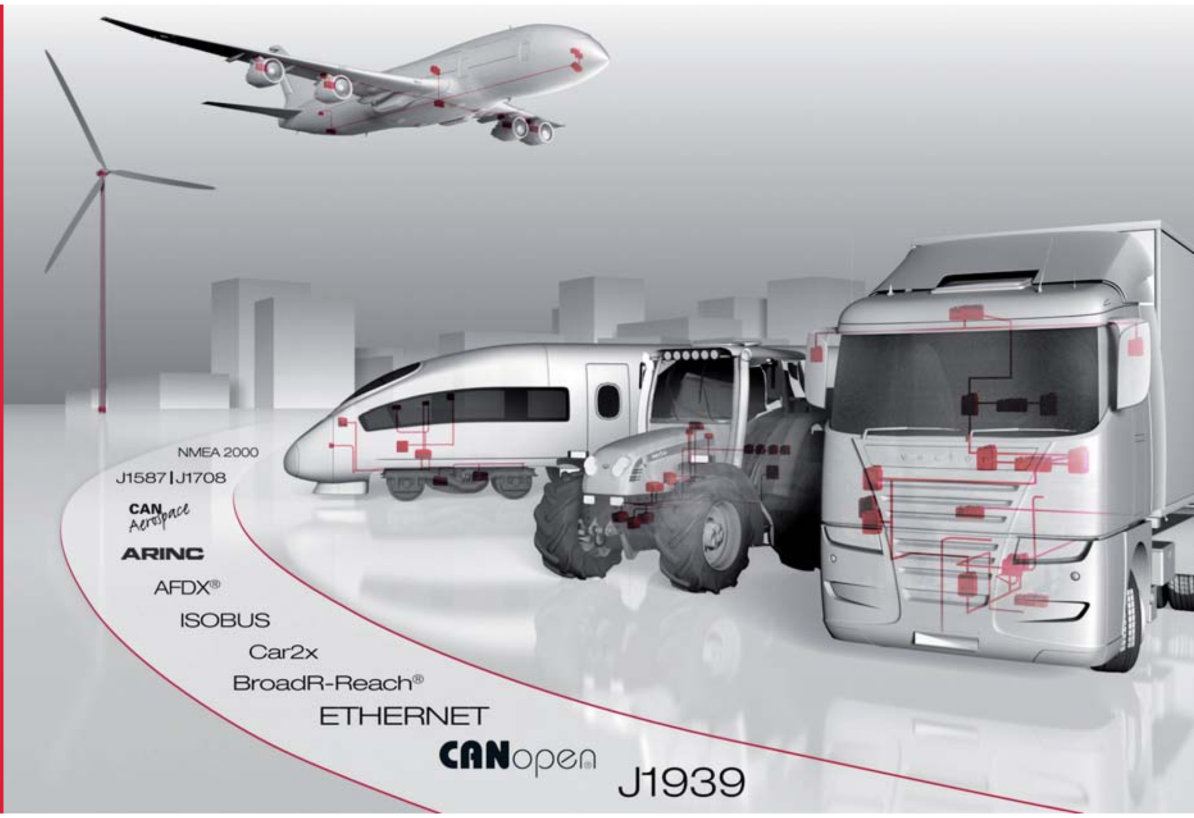
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CANopen on track – IEC 61375-3-3 voted positively

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In 2014, Stadler will deliver its Flirt trains to the Gysev local train operator in West Hungary

It is a long time ago that CiA members requested to standardize internationally CANopen for the use in rolling stock. The very first IEC meeting on this topic went back to February 2005 in Verona (Italy). The ad-hoc task force "Train communication Network" had invited me to present the status of CAN applications onboard of rail vehicles. In the following years, CiA experts especially Reiner Zitzmann represented CiA in the Working Group 43 of the IEC Technical Committee 9. He was appointed as editor of the IEC 61375-3-3 document named "Electronic railway equipment – Train Communication System (TCN) – Part 3-3: CANopen Consist Network". The standard was finally approved unanimously by April 2012. After seven years, CANopen became an internationally accepted network in rail vehicles.

But already in the mid of the 90ties Vossloh Kiepe (Germany) introduced CANopen technology in its trams followed by their colleagues developing diesel locomotives. There are other CiA members supporting CANopen in devices designed for usage in rail vehicles. Selectron offers since many years control systems based on CANopen as well as MEN, Luetze Transportation, Sys Tec, etc. Other CiA members provide CANopen compatible diesel control systems, e.g. MTU and Voith. CANopen ▷

The DE 18 four-axle diesel-hydraulic locomotives by Vossloh provide an automatic start-stop eco drive system, slip protection, and driver assistance has been mainly used in light train vehicles (trams, undergrounds, commuter trains, etc.) and diesel locomotives. In some rail vehicles, CANopen is deeply embedded, for example in door control systems and in brake systems.

The Flirt train by Stadler (Switzerland) is one of the first CANopen references for rail vehicle applications. Some 758 of these trains have been sold so far. Windhoff was another early bird of CANopen users in rail vehicles. The German company made and makes modular trains for construction and maintenance of rail nets and overhead catenary systems as well as freight forwarding, fire-fighting, and rescue services. Alstom Transport (Germany) uses also CANopen networks in its Citadis and Coradia trains. Recently the company singed a contract with the Deutsche Bahn (DB) of 38 additional Coradia regional train sets. CANopen is also used in some Chinese metros and commuter trains, for example in many of the rail vehicles produced by CSR (China). Kangni (China) manufactures rail vehicle doors with CANopen interfaces.

In Europe, the Knorr-Bremse IFE division has developed the first CANopen connectable rail vehicle doors end of the 90ties. The company initiated the first CANopen profile for rail vehicle equipment. This CiA 409 device profile was discontinued and substituted by the CiA 424 series. CiA has developed a huge range of device profiles for rail vehicle equipment. Many of them make references to UIC (International Union of Railways) leaflets. The organization has developed the data format of process data for many units such as brakes, doors, etc. The CANopen SIG (Special Interest Group) "Rail vehicles" has mapped those data objects to the CANopen object dictionary and specified additional necessary data objects. Unfortunately, the SIG is not more active. But that does not mean nobody is using these profiles. In my experience, the companies supplying to rail vehicle manufacturers as well as the train makers are quit closed. This means, some of them use "secretly" the CiA profiles dedicated for rail vehicle applications. I know that in some East European countries, these profiles have been partly implemented.

Of course, it would be better, when CiA submits its profiles for international standardization. But this is politically not that easy. Some parties wanted that IEC standardizes the UIC leaflets. But the UIC objected, because the both organizations could not agree on copyright and business model issues. ◀

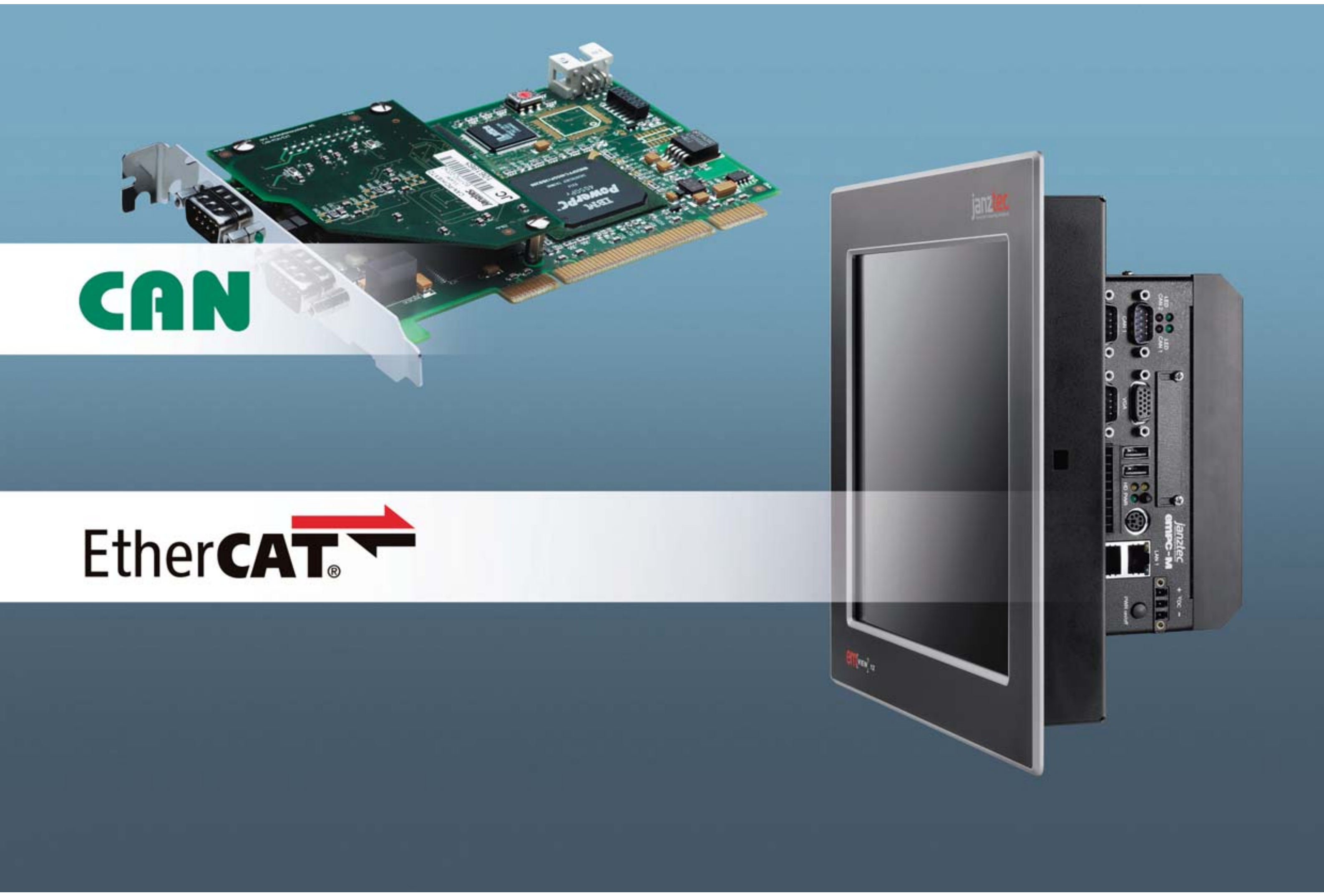
Content of IEC 61375-3-3

The international standard is part of the Train Communication Network series. It specifies the CAN physical layer in more details in order to meet the specific requirements of rail vehicle applications. It also specifies a recommended practice for CANopen communication data objects to improve the interoperability of CANopen devices dedicated for rolling stock. There are also some recommendations added for the CANopen network management. In many cases, there are just references to CiA documents.

The clause describing the gateway to the train backbone network is completely new and not available in any CiA specification. It specifies the services and protocols to access the CANopen device from a device connected to the backbone network. The protocol is based on ASCII syntax for the commands and the responses. This approach is similar to the CiA 309 gateway specification.

Luetze Transportation outsourced

Beginning of this year, Luetze has established the Luetze Transportation GmbH, which is now responsible for the development and production of devices dedicated for any kind of transportation including rolling stock. The daughter company is managed by André Kengerter.



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emPC

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Cover story

The very first IEC meeting on international standardization of CANopen for the use in rolling stock went back to February 2005 in Verona (Italy). After seven years, the IEC 61375-3-3 document named “Electronic railway equipment – Train Communication System (TCN) – Part 3-3: CANopen Consist Network” was unanimously approved by April 2012.

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Rail vehicles

Software

Tool

Hardware

Developed for train applications

The Inducom 9 series of 9-pin D-sub connectors by Harting (Germany) are designed for use in rail-vehicles. Using the connector dedicated for CAN applications, it is possible to realize a T-connection allowing disconnection of a device without interrupting the bus line. The component comprises a metal housing with two cable entries, two hexagonal screws with UNC 4-40 threads, and two cage clamps.

The labyrinth design of the connector metal hood guarantees together with its crimp flange technology a good EMC/RF performance with shielding attenuation greater than 60 dB at up to 500 MHz. The connectors may be used for rail-vehicle applications compliant to IEC 61375-3-3 (CANopen-based train consist network). The pinning should be compliant to CiA 102.

More information about products you find on www.can-newsletter.org

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CANopen panel-PC controls Italian trams

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Figure 1: 6000 series tram operating in Turin

The 6000 series tram is a modern vehicle operating in the city of Turin and Catania in Italy. It has security systems on-board, including an interactive diagnostic monitor installed in the driver's cabin. This monitor is a vital component of the tram and its malfunction causes the tram to become non-operative and requires the vehicle to be returned to the depot for maintenance. This monitor is not just a display as its name suggests, but an embedded computer with display capability that works as a HMI (human machine interface) for the driver.

The monitor previously developed by the tram manufacturer was afflicted by severe design issues. It had problems related to the environment (extended temperature range and humidity). Turin is a city with cold winters and hot summers while Catania is very hot in summertime.

In fall 2008, LVD Systems, the local representative of Janz Tec in Italy, proposed to the local transportation company (GTT) a monitor solution based on the EmView series from Janz Tec (Germany). The chosen 8-inch Panel-PC is based on ARM architecture running embedded Linux.

The diagnostic monitor was a one-to-one replacement of the previous device, requiring no modification to others sub-systems on-board to avoid complex qualification procedures. The former monitor communicated with the main supervisor computer through an EIA-485 line with a proprietary protocol, which encapsulates VT100-like graphical commands plus custom extensions and other tram status information. It also used physical push buttons to receive commands from the driver.

In order to make the EmView to become a replacement component, Linux with QT Embedded from Nokia was chosen as operating system. Real-time patches were applied to the Linux kernel in order to comply with the strict timing requirements of the protocol. Every incoming packet must be acknowledged after 2 μs from reception and not later than 5 μs. A missing acknowledge would cause the tram to stop for security.

After a complex work of reverse engineering LVD Systems completed the software and the first prototype was delivered to the customer. Physical push buttons were replaced by touch-screen buttons reducing the cost of integration and maintenance.

First units were sold to Turin City public transport company (GTT), later also Catania public transport company bought some units to replace former malfunctioning diagnostic monitors.

CAN-based solution

The CAN network has been selected to connect all the devices for the command-and-control system of the Torino city train. The software implementation is a

▷

Figure 2: The EmView panel-PC installed in driver's cabin

Figure 3: Tram diagnostic screen

custom protocol compatible with the CANopen specification (CiA 301). This allows the use of standard COTS (commercial off-the-shelf) CANopen devices as well as special custom devices for the specific needs of the city train. In order to reach this result a special SDO (service data object) has been implemented with a COB-ID (communication object identifier) compatible to the CANopen specification. Standard frame format (11-bit CAN-IDs) is used to communicate among devices. The supervisor/master of the system used the CAN interfaces (Vmod-FCAN) by Janz to interface all the nodes.

The used protocol is based on two communication services: Write PDO (process data object) and Read PDO. In order to keep under control all the devices and activate them, a loop query was generated by the CANopen NMT master periodically. Depending on the CAN bit-rate, this guarantees to detect occurred failures and satisfy the system requirements. Via the Em-View-8T/A400 monitor the operator may read the alarm status of each device in the system. ◀

Company background

LVD Systems offers embedded solutions targeted on transportation, industrial, avionic, telecom and scientific market. With more than 20 years of experience, the company develops hardware and software solutions based on customer necessities. The system integration solutions make use of COTS (commercial off-the-shelf) products.

Rail automation system speaks CANopen

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Key milestone

On 2nd November 2011, the 500th Coradia Lint was leaving the Alstom factory. This is a key milestone for the rail vehicle manufacturer. This vehicle is part of an order for 28 Coradia Lint rail vehicles for the Lower Saxony rail company (Germany), who ordered their first Coradia Lint from Alstom in 1997. Since the first vehicles were delivered in 2000, the company has sold a total of 621 Coradia Lint trains in Germany, the Netherlands, Denmark and Canada to private and state-run transport companies and providers. The 500th vehicle reaches speeds of up to 120 km/h, has 129 seats and is equipped with accessories for people with limited mobility (e.g. a wheelchair ramp) and for visually impaired passengers (guide bars on the external doors).

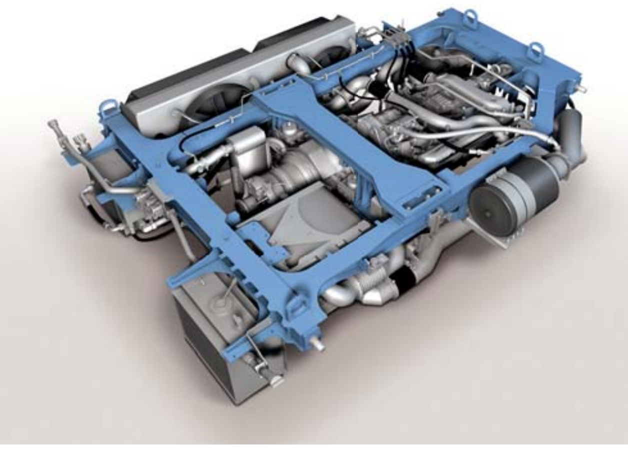

Figure 1: The MTU Powerpacks for Alstom's Coradia Lint 54 and 81 railcars

Tognum is to supply a total of 206 MTU Powerpack Automation systems (drive units) to railcar manufacturer Alstom (Germany) from 2012. The drive units are interconnected with the central train control system via CANopen. Alstom will install the underfloor diesel units in 56 regional trains, which will go into service with Deutsche Bahn (German national railway company) in the Greater Cologne and Eifel region, known as the Cologne Diesel Network, from December 2013. The drive units meet EU Stage IIIB emissions regulations, which come into force in 2012. The new Coradia Lint 54 and 81-type trains are Deutsche Bahn's first diesel multiple units to be fitted with SCR catalyzers for exhaust gas cleaning and nitrogen oxide emissions reduction. In addition, in-engine technology will reduce particulate emissions by around 90 %. In conjunction with an engine management system, the introduced technology reduces diesel fuel consumption and therefore CO_2 emissions by up to 5 %.

The Powerpacks with 390 kW diesel engines of the type 6H 1800 R85L are scheduled for delivery between March 2012 and September 2013. The two-car Coradia Lint 54 vehicles will each be fitted with three Powerpacks whilst the three-car Coradia Lint 81 versions will get four Powerpacks each. On each vehicle, one of the three (or four) Powerpacks may be shut down to achieve savings on fuel and operating costs depending on the route involved. The units, also known as "Traction Powerpacks", will be supplied in a configuration without assemblies such as on-board power gensets or aircon compressors. As an operator, Deutsche Bahn also benefits from the opportunity to tailor the package supplied to the service operated. Consistent savings on diesel fuel mean increased cost-efficiency over the entire life of the vehicles.

Figure 2: Three MTU Powerpacks will power Alstom's Coradia Lint 54 diesel railcars operating in the Cologne Diesel Network

Powerpack system

The Powerpack modular automation system allows controlling, regulation and monitoring of the entire drive system. It can be deployed for diesel-mechanical drives, as well as for diesel-electric drives. Automatic power adjustment or engine shutdown by the integrated safety system is supported. Traction optimization is achieved by the integrated load management (torque control) feature depending on the consumers connected (e.g. generator, compressor, etc.).

The automation system includes the SAM (ser-

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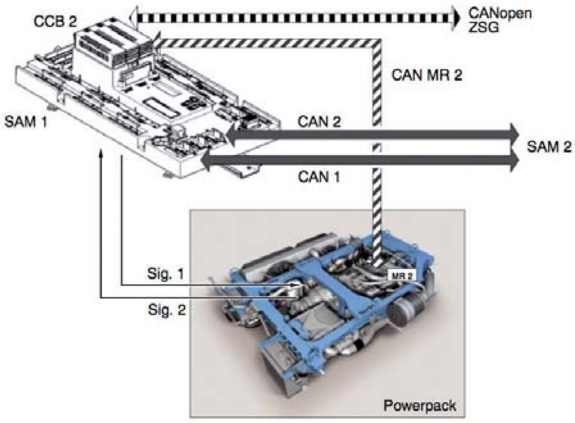

Figure 3: Typical configuration of the Powerpack and its electronic devices

vice and application module) interface module. It is used to exchange control signals and status information with the central controller of the vehicle. The interface module provides three CAN interfaces each realized by a CAN communication board (CCB) with a separate processor handling the CANopen protocol. Ethernet interface and various I/O functionality are also available. Supported CANopen specifications include CiA 301 (basic application layer functions; version 4.1), CiA 302 (additional application layer functions e.g. NMT master) and CiA 307 (Framework for maritime electronics). The CiA application profiles for train vehicle control networks (CiA 421) and for rail vehicle power drive systems (CiA 423) are supported as well. Programming is possible using the IEC 61131-3 languages. Software update may be done using a CF card. Diagnosis may be realized via the integrated web server and the mini display. The IP40-rated device is designed for continuous operation at environment temperatures from -40 °C to +60 °C.

CANopen communication

The automation system communicates with a fix bit-rate of 125 kbit/s and acts in its standard configuration as an NMT (network management) slave. This means, that the device requires an NMT master to be started. The node-ID varying from 1 to 127 is configurable. As no SDO (service data object) communication is supported, the device does not really comply with the CiA 301 specification, which mandatory specifies to provide at least one SDO client on a CANopen device. Thus, the device transfers its status data and receive commands via PDOs (process data objects). Static PDO mapping is supported, which means that the content of the messages may not be changed while the device is running (NMT state “Pre-operational” or “Operational”). The PDO 1 to PDO 4 use the CAN-IDs from the pre-defined connection set as given by the CiA 301. If more than four PDOs in transmit or receive direction are required, a CAN-ID allocation scheme is pre-defined by the manufacturer. The PDOs are sent cyclically each 5 s. The device produces a Heartbeat message (signals that it is alive and works in a required state) every 500 ms. As an option, the drive unit may be provided as a self-starting device, which may go from the NMT state “Pre-operational” to “Operational” without a command from the NMT master. ◀

CANopen in rail vehicles

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Innotrans gag

At the Innotrans 2012, the company will present in the hall 6.2, stand 123, the driver simulation software "Locsim". The visitors may test the software steering a simulated rail vehicle in a demonstrated operators stand.

Figure 1: Chinese locomotives from CSR Quishuyan

Selectron (Switzerland) has supplied its TCMS system (Train Control and Monitoring System) for integration in the locomotives from CSR Quishuyan (QSY), which is one of the market-leading locomotive manufacturers in China. QSY will implement the system with support from Selectron China and Switzerland. The vehicles will be shipped to company's customer Pacific National (PN) in Australia, which is planned for 2012. The AC-powered vehicles will be used for coal transportation in Queensland's mining industry. Four locomotives are grouped as two sets in order to pull up to 120 rail cars. This results in train lengths of up to 3 km.

The TCMS system is based on CANopen and Ethernet. It is a platform for generic train automation applications designed for harsh environments. Regarding shock, vibration, temperature, EMC, system's modules are in accordance to the rail standard EN 50155. The whole system can be designed and programmed with the Symphony tool family, which was recently updated by the company (also in regard to CAN/CANopen functions). The tool, based on IEC 61131, allows configuration, communication, diagnostic and system management. For HMI configuration while the development phase, the Maestro Designer tool is used.

The Swiss company also supported the refurbishment of a guard's van Bcm61 from Ralpin (Switzerland). The latter operates a rolling autobahn (Rola) through the Swiss Alps. In the Rola terminals, complete trucks are laden on the train. The truck drivers travel in the guard's van. Daily, up to 22 Rola trains run between Freiburg (Germany) and Novara (Italy). Two Rola trains operate between Basel and Lugano (Swiss). Some of the trains are equipped with the Bcm61 guard's van, which was modernized in 2011. The van with up to 48 sleeping berths is air-conditioned. Selectron supplied the electronic control devices interconnected via CAN, EIA-485 and Ethernet. The central control of the van's electronics is done with the CPU 831-TG. The CPU 727-T controls the air-conditioning. Further controller and expansion modules were also deployed.

The train standard (EN 50155, Railway applications – Electronic equipment used on rolling stock) has been launched in 1996. CAN is able to fulfill this standard regarding EMC, shock, vibration, temperature and long-term availability. The IEC 61375-3-3 standard (Electronic railway equipment – Train Communication System (TCN) – Part 3-3: CANopen Consist Network) was released in April 2012. Thus, CANopen became an internationally accepted network in rail vehicles.

Today CAN and CANopen solutions are already running on several thousand trains worldwide in applications on new trains, refurbishment projects, sub-systems and in infrastructure. Different types of trains such as locomotives, coaches, urban/regional trains, track maintenance machines, high-speed trains, trams, monorails, metros are running with CAN/CANopen systems. A number of subsystem suppliers e.g. for propulsion, air-conditioning, brake, door, lavatory and light have designed CANopen as a standard interface on their devices. The success of CAN/CANopen on trains is based on its robustness, open structure, flexibility, long-term availability as well as a large number of available CAN-controllers. ◀

Figure 2: Guard's van Bcm61 from Ralpin

You CAN get it...

Hardware & software for CAN bus applications...

LINUX device driver available

PCAN-USB Pro

High-speed USB 2.0 interface with galvanic isolation for connecting up to 2 CAN and 2 LIN busses.

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NEW

CAN bus diagnostics with trace function

PCAN-Diag 2

PCAN-Diag 2 is a handheld CAN bus diagnostics unit. The new model offers enhanced functionality:

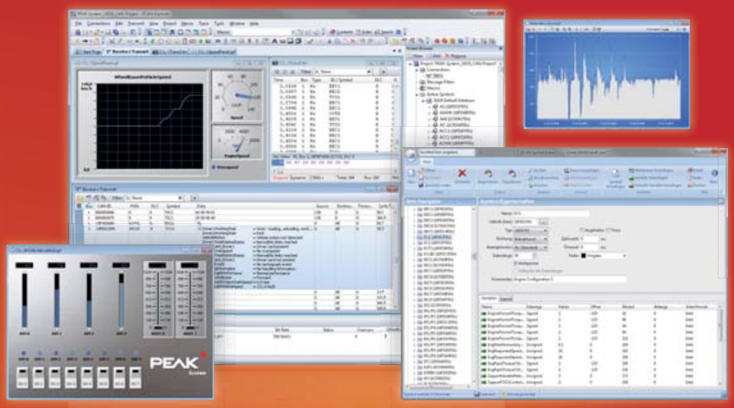
- Clear CAN traffic representation in lists, configurable symbolic representation of received messages
- Transmission of individual CAN frames or CAN frame lists
- Built-in 2-channel oscilloscope for detailed analysis of the differential CAN signal or an optional external signal, triggering by CAN IDs or other events
- Bit rate detection, bus load and termination measurement
- Windows® software for easy device configuration and transmit list definition, upload via USB connection
- Storage of diagnostic results (CSV, BMP) on an internal 1 GB mass storage USB device

PCAN-PCI Express

CAN interface for PCI Express slots. 1, 2, and 4-channel versions with galvanic isolation available.

PCAN-Repeater

Repeater for the galvanic isolation of 2 CAN bus segments, bus status display, switchable termination.



PCAN-Explorer 5

The universal tool for developing and monitoring CAN networks.

- Extensive user interface improvements: File management via projects, configuration of all elements with the property editor, and window arrangement using tabs
- Simultaneous connections with multiple networks / CAN interfaces of the same hardware type
- Configurable symbolic message representation
- Data logging with tracers and the 4-channel Line Writer
- VBScript interface for the creation of macros
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- User interface language in English or German

PCAN-miniPCIe

CAN interface for PCI Express Mini slots. Single- or dual-channel versions with isolation available.

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Development platform with CAN, GPS, and GPRS. Interpretation of OBD-2-, FMS-, DTCO-, & CiA® 447.

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PEAK System

Transport protocols and message processing inside Linux

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Today CAN networks are used in a wide range of control applications. Usually the content-based addressing is practiced to transfer information by sending single CAN frames. In the automotive context periodical transmissions are used to detect the absence of the data source within a reasonable time. E.g. when the period status information of a CAN controlled media player is not received every 200 ms the media player can be disabled in the HMI of the vehicles Infotainment system.

Additionally so-called CAN transport protocols are used in the vehicles on-board diagnostics (OBD) to provide a virtual point-to-point connection between the diagnosis tester and the CAN-connected ECU. With help of these CAN transport protocols (like ISO 15765-2) PDU (process data unit) length up to 4095 byte can be transferred via CAN, which is used e.g. for firmware updates.

Character device drivers for CAN

Having these two use cases in mind the known CAN drivers for Linux were not able to fulfill any of them appropriately in 2002. Due to the fact that known CAN drivers based on the character device driver model the interface to the CAN controller was simple and direct – as known from character based serial drivers. The various CAN character device drivers presented a more or less abstract programming interface that is specific to CAN controller capabilities or vendor requirements. Especially the functionality provided by the CAN driver is reduced to apply CAN identifier filters.

> *“For novice CAN application developers there is no break in the programming philosophy known from other networking technologies and the stable socket programming interface promises a protection of investment. Especially CAN drivers that found their way into the Linux mainline kernel are continuously maintained and fixed in a community process so that they stay operational for all upcoming Linux kernel versions.”*
>
> *Dr. Oliver Hartkopp*

To implement content filters for the payload of cyclic CAN messages these messages had to be processed in user-space context. E.g. if only a state change in the payload was relevant for the application each received CAN message had to be transferred from kernel-space into user-space for a comparison with the former one.

The implementation of a CAN transport protocol has to fulfill restrictive timing requirements down to a few milliseconds. This cannot be ensured in the user-space context where several processes in a multitasking system share the same CPU. Depending on the system load the processes get their CPU time regulated by the system scheduler and the resolution of the system timer. The common alternative to implement CAN transport protocols for multitasking operating systems is to have a separated embedded CAN CPU or to use a real-time variant of the selected multitasking operating system (OS).

CAN networking in Linux

The point-to-point network communication in multitasking operating systems is well known from the Internet protocol (IP) communication. Different connection oriented and connectionless protocols based on the IP like the TCP and UDP are state of the art in common operating systems. Adapting this internet networking technology to realize the similar requirements of CAN transport protocols leads to an implementation of the CAN access inside the OS network stack.

This approach has several advantages over the formerly described character device driver model:

- Standard programming interfaces for system calls (‘network sockets’)

▷

- Standard network driver model known from Ethernet drivers
- Established abstraction layers in the network stack
- Communication protocols implemented inside the operating system context
- Multiuser access to the network

The definition of a network device driver interface for CAN is the first step to unify the CAN network access. As known from Ethernet networking the driver abstraction allows the replacement of networking hardware without modifying the user applications like e-mail clients or web browsers. On the other hand the CAN network device definition allows the hardware vendor to focus on the driver development without being in charge to specify and implement user-space programming interfaces and tools.

The direct access to network devices can be performed with a privileged access to the PF_PACKET socket interface. But using the PF_PACKET protocol family sockets for CAN network devices has some vital drawbacks:

- Privileged access rights are needed (administrator only)
- No full network transparency for local CAN applications
- No efficient traffic filtering based on CAN identifiers
- No integration of CAN specific (transport) protocols

Especially the missing network transparency (second bullet) turns out as a knock-out criterion in a multiuser environment, as different CAN applications would have a different view of the existing CAN traffic.

The PF_CAN network protocol family

To overcome with the limitations caused by accessing CAN network devices with PF_PACKET sockets a new protocol family for the Controller Area Network has been created. The integration of this PF_CAN protocol family into the Linux network stack can be derived from existing network protocol families like DECnet, Appletalk or AX.25 that also use the Linux networking infrastructure with different networking hardware and protocols.

To establish a separate data path for CAN messages and CAN devices the data buffers and network devices are identified with new type definitions:

- ETH_P_CAN identifies network data buffers that contain CAN messages
- ARPHRD_CAN identifies CAN network devices that handles network data buffers marked as ETH_P_CAN type

Based in these definitions a new PF_CAN protocol family implementation can register itself to be responsible for ETH_P_CAN marked buffers containing CAN messages.

Together with the PF_CAN/AF_CAN value definitions and a new CAN socket address structure the missing link for the socket-programming interface for user-space applications is established. From this point the protocol family PF_CAN provides a framework that manages the CAN data flow from the user to the CAN network driver and vice versa.

Inside the operating system PF_CAN offers programming interfaces for various CAN based protocols. Comparable to UDP and TCP being different protocols of the protocol family PF_INET for internet protocol networking new CAN relevant functionalities can be hosted inside the PF_CAN framework. The different CAN protocols can be accessed from user-space applications with different protocol numbers that are functional available when a CAN protocol implementation registers itself at the PF_CAN framework.

To provide a multiuser access to CAN traffic the PF_CAN core offers inter- ▷

SPI CAN driver for Linux

On the 13th iCC, Sakari Junnila introduced in his presentation the Wapice Custom Can Driver (WCCD), which is targeted for embedded Linux and optimized for ARM-based platforms. He presented also the results of some measurements comparing the WCCD approach with SocketCAN and LinCAN drivers. They author working with Wapice, a Finnish CiA member, has tested his driver's performance with extremely high bus-loads and have been able to receive over 20000 CAN messages per second. To achieve this, they made significant amount of optimizations also to the platform and low-level CAN and SPI driver code for the MCP 2515 controller outside of the SocketCAN driver framework. But as the evaluation of the executed performance measurements showed, the usage of the WCCD driver architecture provides benefits over alternative CAN driver implementations.

The biggest downside for the usage of the WCCD is the lack of a standard interface. Standard software cannot be used with it without porting it to the WCCD driver API. However, embedded systems applications are often proprietary and developed to some specific purpose.

Reference: Sakari Junnila and others – Design of high-performance CAN driver architecture for embedded Linux. In: 13th iCC proceedings, Nuremberg 2012.

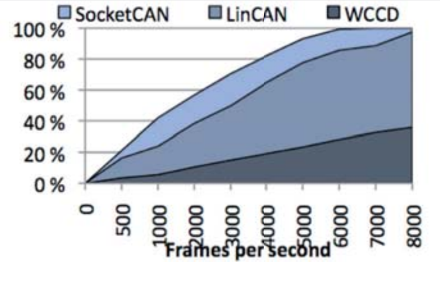

Figure I: CPU load for received messages

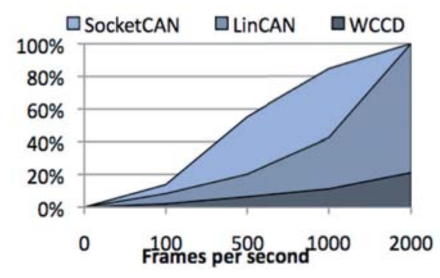

Figure II: CPU load for echoed messages

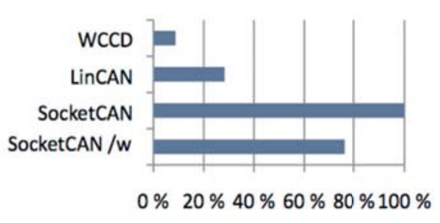

Figure III: CPU load when transmitting 1000 messages per second

Summary

Since version 2.6.25 (issued 2008-04-17) the Linux mainline kernel supports the network protocol family PF_CAN providing standardized programming interfaces for CAN users and CAN driver developers. This article provides an overview of the implemented technologies and challenges to integrate CAN interfaces into a non-real-time multiuser/multitasking operating system. Due to the standardized network driver model for CAN hardware a wide range of CAN controllers and CAN IP-cores are supported by Linux out-of-the-box. In opposite to usual embedded CAN ECUs the Linux networking system is designed to handle multiple CAN applications using multiple CAN networks at the same time. The integration of the CAN infrastructure into the networking stack allows implementing CAN transport protocols like ISO 15765-2 or high-performance CAN frame gateways inside the operating system context. The article provides solutions for expected prioritization issues when executing multiple CAN applications and summarizes requirements for Linux-preferred CAN controller concepts.

SocketCAN: The “official” CAN-API for Linux

Marc Kleine-Budde from Pengutronix discussed in his 13th iCC paper the tradeoffs of the SocketCAN approach. He also presented the CAN-BCM broadcast manager, which is used for example to support the J1939 and ISO 15765-2 transport protocols. The first ideas of a socket-based networking stack for CAN devices went back to 2002. There were several CAN implementations for Linux available back then, and some still are. Nowadays, SocketCAN is the official CAN application programmer interface (API) fo the Linux kernel. It has been included in the kernel more than three years ago. Although, the kernel internal interfaces are stable, there is a constant evolution in the kernel going on. Re-evaluation of existing concepts, improvements, additional features and consolidation doesn’t stop before the SocketCAN core or it’s drivers. For example, the error handling in the CAN drivers is going to be consolidated and unified.

Reference: Marc Kleine-Budde – SocketCAN: The official CAN API of the Linux kernel. In: 13th iCC proceedings, Nuremberg 2012 (see < http://www.can-cia.org/fileadmin/cia/files/icc/13/kleine-budde.pdf >)

nal functions to CAN protocol implementations to send and receive CAN frames:

`can_send()`
Send a data buffer containing a CAN frame to a CAN device. Performs sanity checks for CAN frames (e.g. dlc) and ensures the local echo functionality.

`can_rx_register()`
Register a callback function that is executed on the reception of a CAN identifier that matches the given mask/value filter.

`can_rx_unregister()`
Remove a formerly registered subscription.

Depending on the given mask/value filter different filter-sets are used to reduce the CPU consumption when checking the registered subscriptions at runtime. The per-interface created filter-sets are checked in a software-interrupt on every CAN frame reception. Due to the described multiuser requirement the CAN drivers intentionally do not support any system wide CAN identifier filters. The performance of the software-interrupt based CAN filters has been evaluated in [4].

Higher-layer protocols in PF_CAN

The protocol CAN_RAW offers a similar programming interface as known from the CAN character device drivers. Analog to opening a character device file in Linux (e.g. `/dev/can0`) the CAN application programmer creates a network socket and reads/writes specific data structures representing CAN frames.

Additional to the fact that multiple instances of CAN_RAW sockets can be created at the same time several different CAN identifier filters can be applied to each created socket separately. Due to the different filters for each CAN_RAW socket a specific view to the selected CAN network traffic can be archived and separately handled by different applications and users on the system.

The CAN_RAW sockets identifier filters reference directly to the per-interface filter-sets provided by the PF_CAN framework. The simple callback registration delivers the subscribed CAN frames directly to the requesting socket instance to be read by the user-space CAN application.

In automotive networks, the CAN messages are not only used to transfer signal values in the CAN frames payload. Sending CAN frames periodically e.g. every 200 ms allows detecting failures of the originating CAN node. This mode of operation has two drawbacks regarding the bus-load and the message processing. Even when the reception of CAN traffic is reduced by filters and/or message buffers the CAN frame payload needs to be checked whether the relevant signal has changed.

To reduce the effort for payload content filtering the CAN broadcast manager protocol (CAN_BCM) has been integrated into

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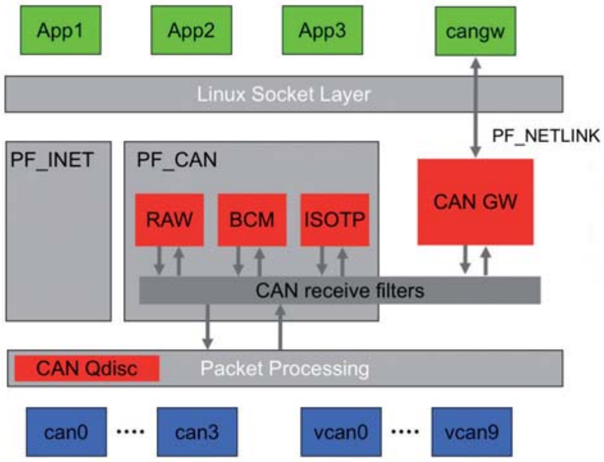

Figure 1: CAN network layer protocols and CAN frame processing


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ETHERNET POWERLINK
PROFI NET INDUSTRIAL ETHERNET
Your Product
Engineering
Know-How
Professional Tools
Protocol Stack


EtherNet/IP
DeviceNet
SAE J1939
MODBUS
SERCOS interface

PF_CAN. The CAN_BCM is a programmable content filter and timeout handler for incoming CAN frames and can also manage the sending of cyclic messages in operating system context.

Due to the Linux high-resolution timers the precise sending of messages is independent from process scheduling. The content filter that checks changes in the 64 bit payload is processed in the software interrupt at CAN frame reception time to ensure that only relevant changes are passed to the CAN application in user-space.

CAN_BCM transmission path functions:

- Cyclic transmission of a CAN message using a given interval time
- Redefinition of CAN message content and interval timers at runtime
- Counting of performed intervals with automatic switching to a second interval time
- Immediate transmission of changed CAN message content with/without starting the timer interval
- Single transmission of CAN messages

BCM receive path functions:

- Receive filters to check changes in relevant CAN message elements (payload, data length code)
- Receive filters for single CAN identifiers (no content matching)
- Receive filters for multiplex CAN messages (e.g. with indices inside the CAN message payload)
- Receive filters for monitoring the data length code of the CAN message
- Respond to CAN remote frames
- Time-out-monitoring of CAN messages
- Reduction of the update rate for content filter changes messages (throttling)

Depending on the use case payload content filtering and throttling can provide a significant reduction of the system load (see [5] p. 102-103). Additionally the comfortable CAN_BCM socket-programming interface reduces the complexity of the CAN application and supersedes a complex and imprecise timer handling in user-space.

Transport-protocols in OS context

Known solutions that implement CAN transport protocols use an embedded CAN processor in the CAN hardware interface to ensure the ambitious protocol timing requirements. The availability of Linux high resolution timers for the precise sending of CAN messages lead to the question if these timing requirements of CAN protocols can be handled inside the PF_CAN framework. A public available implementation [6] of the ISO 15765-2 CAN transport protocol has been evaluated and compared to a commercial diagnosis tool. It turned out that minimum response time of the Linux implementation was at least twice the time and in the worst case ten times longer than with the embedded CAN CPU solution. As the 4 ms delay of the worst-case scenario was still covered by the specified protocol timeout of 1000 ms the PF_CAN based implementation is conform to ISO 15765-2. Besides the measured overall timing ranges the open source implementation processed the CAN protocol messages two times faster than the embedded solution (average values).

CAN frame routing using PF_CAN

In Internet protocol networking the routing and forwarding of IP traffic through different network devices is common practice. The routing and modifying operations for IP packets are based on IP addressing schemata. As the qualified CAN addressing is based on the CAN identifier and the CAN interface the existing routing implementations inside the operating system context are not suitable for the Controller Area Network.

Attempts to route CAN frames efficiently with user-space applications like candump failed through the existing process scheduling which lead to drops and non-deterministic delays depending in the size of the per-socket receive buffer size.

To integrate an efficient CAN message routing in Linux the created CAN gateway (CAN_GW) makes use of the PF_CAN filter subscription infrastructure. The registered filters trigger callback functions in the CAN gateway where the received CAN frames can optionally be modified before they are sent to the outgoing CAN interface. The one-hop CAN message forwarding supports the following on-the-fly modifications of the CAN frame elements CAN-ID, CAN-DLC, CAN-DATA:

- AND: logical ‘and’ element with value
- OR: logical ‘or’ element with value
- XOR: logical ‘xor’ element with value
- SET: set element to new value

After performing one or more of these optional CAN frame modifications in the described order a potentially corrupted payload data checksum can be built on demand. Additional to a simple XOR checksum calculation for a given data set, three CRC8 profiles can be selected that can calculate a CRC8 value based on an individual 256-byte CRC table. With this functionality the CAN gateway is able to create Autosar End-to-End-Library compliant CAN messages on-the-fly even after modification.

The implementation of the CAN gateway is optimized towards performance as the optional modification and checksum calculating operations are executed in the software interrupt context. Detailed performance measurements of CAN_GW have been made. The CAN gateway implements the Linux routing capability for the protocol family PF_CAN and supports the netlink configuration interface that is also used for the routing configuration of internet protocol data.

CAN frame traffic shaping

Due to the multiuser capabilities of the CAN network-

▷

deltaT	ID	data
0.200	123_h	00 00 00 20
0.200	123_h	00 00 00 21
0.200	123_h	00 00 00 22
0.100	730_h	02 03 04 05 06 07 08 09
0.001	730_h	02 03 04 05 06 07 08 09
0.001	730_h	02 03 04 05 06 07 08 09
0.001	730_h	02 03 04 05 06 07 08 09
0.001	730_h	02 03 04 05 06 07 08 09
(500 CAN frames later)		
0.001	730_h	02 03 04 05 06 07 08 09
0.001	730_h	02 03 04 05 06 07 08 09
0.001	123_h	00 00 00 23
0.001	123_h	00 00 00 24
0.001	123_h	00 00 00 25
0.001	123_h	00 00 00 26
0.200	123_h	00 00 00 27
0.200	123_h	00 00 00 28

Table 1: Data traffic without shaping


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CANopen Product Guide
Welcome to the CANopen Product Guide
J1939 Product Guide


KNIEL
energy 1500

Summary

The Linux subsystem for CAN standardizes the programming interfaces for CAN driver programmers and CAN application programmers. In comparison to a programming interface with a character device driver model, the chosen approach allows to implement various CAN specific communication protocols inside the operating system as well as the reuse of established and powerful networking techniques like network traffic control. The clear and simple network device driver interface known from Ethernet drivers leads to an easy exchangeability of CAN hardware without changing the existing applications. The open-source development process in the Linux kernel enables the contribution of new CAN drivers and CAN based protocols for everyone in an open community and is independent from single vendors.

Related articles

This article as iCC proceeding:
< http://www.can-cia.org/fileadmin/cia/files/icc/13/hartkopp.pdf >
Dr. Sakari Junnila: Design of high-performance CAN driver architecture for embedded Linux
(in iCC proceedings 2012; see < http://www.can-cia.org/fileadmin/cia/files/icc/13/junilla.pdf >)

ing implementation in Linux a challenge to manage the host access to a single CAN medium arises. For example a CAN application A sends status information on CAN-ID 0x123 every 200 ms. Application B sends a 4095 byte PDU via ISO 15765-2 without a tx-delay requested from the communication partner. This leads to an expected transmission sequence shown in the Table.

Due to the fact that the ISO 15765-2 protocol pushed more than 500 CAN frames en-bloc into the CAN network device queue the relevant status information is not send on the CAN netwok for the ISO-TP frames transmission time. Depending on the used bitrate the block transfer time the cyclic status information can be inhibited which leads to inconsistencies and timeout errors in the data sink.

The described data flow effect is a known problem in Internet protocol networking too. To be able to browse the web in a smooth way while having peer-to-peer data communication the traffic can be controlled depending on its content. This so-called ‘traffic shaping’ for peer-to-peer connections is part of a traffic control framework inside the Linux networking. The various traffic control capabilities to prioritize, throttle or drop packets are designed to handle Internet protocol traffic and are not aware of Controller Area Network identifiers. Therefore the classifiers to sort and separate packets into network queues have been extended with a new CAN classifier implementation.

This CAN classifier support enables the usage of the entire traffic control (TC) capabilities of the Linux networking subsystem although not every queuing discipline is suitable for CAN use cases. The traffic control configuration requires administrative access rights, which concentrate the host configuration to a single point. This allows setting up the local CAN node fulfilling the requirements of the different CAN applications and the other CAN devices.

This setup can be used to solve the initial example with the modified ‘tc’ tool (see listing).

```
# create a can0 prio
traffic control
handle
$ tc qdisc add dev
can0 root handle 1:
prio

# sort CAN-ID 0x123
to a separate queue
$ tc filter add dev
can0 parent 1:0 prio
1 \can sffid 0x123
flowid 1:1

# sort CAN-ID 0x124
to a separate queue
$ tc filter add dev
can0 parent 1:0 prio
2 \can sffid 0x124
flowid 1:2

# catch the rest
into the default
class
$ tc filter add dev
can0 parent 1:0 prio
3 \can sffid 0x0:0x0
flowid 1:3
```

When the CAN identifier 0x123 is to be sent, the CAN frame is sorted into the priority 1 queue. The frames in the priority 3 queue are sent to the CAN network when the higher priority queues are empty.

An alternative utilization for traffic control can be the throttling of outgoing traffic with a token bucket filter. This can be used to slow down the traffic on a local virtual CAN interface to have a realistic throughput like 125 kbit/s even without real CAN hardware. Usually the runtime created virtual CAN network devices are not limited in bandwidth like the loopback device for local Internet protocol traffic.

Multiuser requirements obviously need to be solved on the host differently than in known embedded systems which has an impact on the CAN network driver implementation. Most CAN controllers provide a set of several transmit objects that can be accessed via different memory registers. Based e.g. on the CAN identifiers stored in the transmit objects an “intelligent” CAN controller is able to decide, which object to transmit first. To be able to specify the sequence of sent CAN messages with queuing disciplines the CAN controller has been configured in a simple FIFO mode. Therefore only one transmit object is used in the Linux CAN network drivers even when the CAN controller itself provides more than one transmit object. To ensure the maximum CAN throughput so-called shadow registers are used if available. Shadow registers allow writing the next CAN message into the CAN controller while the current transmission is in progress.

The CAN classifier for Linux queuing disciplines is currently evaluated with a prototypic implementation. Analogue to the CAN gateway this traffic control approach has the potential to become part of the Linux mainline kernel. ◀


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More than 120 PLCs using Codesys with CANopen

Figure 1: The 3S directors Manfred Werner (left) and Dieter Hess (right)

__Company__
3S-Smart Software
Solutions GmbH
Memminger Str. 151
DE-87439 Kempten

The company's main focus is the development and distribution of the Codesys programming environment and PLC runtime software compliant to IEC 61131-3 programming languages. The offered software is more than a development system: It also includes extensions for motion control or visualization for example. From the start the PLC software features support of different communication systems. In the beginning Profibus was the most requested bus system, nowadays it is CANopen and Ethercat.

__Links__
www.3s-software.com
forum.3s-software.com
www.plcopen.org
www.dor1.co.il
www.humiq.nl

When Dieter Hess and Manfred Werner started in 1994 the 3S - Smart Software Solutions company, the internationally standardized programming languages for PLCs (programming logic controller), known as IEC 61131-3, were just two years old. The PLCopen non-profit association was promoting this standard against proprietary solutions. In those days, so-called Soft-PLCs were quite rare. Nevertheless, the first version of the IEC 61131-3 compliant Codesys (Controller Development Environment) programming environment was released already in 1994. Today is Codesys one of the market-leading PLC software solutions. More than 350 OEM customers have implemented Codesys in their host controllers. The 104-employees company, headquartered in the South of Germany close to the Alps, achieved in the last year a turnover of 10,7 million €. In 2011, there were sold more than 500 000 runtime licenses.

The Codesys software supports all five programming languages defined in IEC 61131-3:

- IL (Instruction list) is an assembler like programming language
- ST (Structured text) is similar to programming in Pascal or C
- LD (Ladder diagram) enables the programmer to virtually combine relay contacts and coils
- FBD (Function block diagram) enables the user to rapidly program both Boolean and analogue expressions
- SFC (Sequential function chart) is convenient for programming sequential processes and flows

In addition, a graphical editor is provided: The CFC (Continuous Function Chart) is a sort of freehand FBD editor. Other than in the network-oriented FBD editor, where the connections between inputs, operators and outputs are set automatically they have to be drawn by the programmer. All boxes can be placed freely which makes it possible to program feedback loops without interim variables.

The programming environment supports CANopen communication and configuration of CANopen NMT slave devices by means of SDO services. It is also possible to send and receive PDOs as well as EMCYs. The runtime system manages and supervises the CANopen NMT slave devices by means of NMT message, Node/life guarding, and Heartbeat. This means the PLC software includes a CANopen protocol stack. But the PLC itself is not a CANopen device, because it does not provide the mandatory SDO default server. This means, the implemented CANopen ob- ▷

> *CANopen is for us one of the most important networks.*
>
> *Hilmar Panzer*

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Figure 2: Wood processing machine using Codesys

ject dictionary is not accessible from the network by means of generic CANopen tools. The CANopen object dictionary is only accessible from the Codesys programming environment. Of course, the programming environment supports to read CANopen-EDS (electronic data sheets) to get knowledge on the connected CANopen devices. The currently implemented boot-up procedure for CANopen NMT slave devices does not read the error register (index 1001h), but follows in general the CiA 302 recommendations.

CANopen is one of the most used network technologies, in particular in mobile machinery. There are no detailed figures about the CANopen licenses available. But it is estimated that in the last year about 250 000 Codesys runtime licenses have been sold with CANopen functionality.

Typical examples for mobile machinery include hydraulic excavators by Terex/O&K, blast hole drill rigs by Sandvik, and harbor cranes by Liebherr. In several of these heavy-duty applications, there are proprietary CAN-based higher-layer protocols and CAN-based J1939 solutions are supported.

The CANopen option is also used in many embedded PLC systems (e.g. for medical devices) and in machine control systems. A typical example is the Vario-shuttle conveyor system by Eisenmann. Another on is the wood processing machinery by Homag. Atlas Copco use Codesys with CANopen in its compressors. The Swedish company produces annually about 30 000 of them. Lenze uses another embedded PLC with CANopen in its programmable motion controllers.

Interesting is that the company's buildings are equipped with PLCs running Codesys and using CANopen networks to link the necessary I/O devices. Hilmar Panzer, the head of the application development department, uses also in his private home Codesys with CANopen.

On request from the market, the software house develops a CANopen Safety solution for SIL 2 (safety integrity level) according to IEC 61508. As an active CiA member, the company participates in CiA technical working groups, especially in the IEC 61131 group jointly organized with PLCopen.

> *"With the Codesys Application Composer users will experience a jump forward in engineering productivity."*
>
> *Dieter Hess*

The recently introduced Codesys Application Composer adds an application level to the IEC 61131-3 programming system. Pre-designed modules can be used to build complete automation applications. Such modules implement parts of machines or plants like pneumatic cylinders, automatic tool changers or temperature controls as well as typical software functions like parts administration or user administration, process control or network management. All engineering aspects of Codesys are included in the modules: program code, I/O assignment, parameterization and visualization. The user structures his machine based on these POUs and connects them in special editors. Integrated generators then automatically produce complete, well-structured IEC 61131-3 applications including a visualization, which can directly be compiled and uploaded to the controller. The generated source code is visible to the user.

This approach opens the door to users, who do ▷

Figure 3: Rock crushing machine with Codesys

Products

- Codesys programming environment: Development system running under Windows for creating PLC application programs compliant to IEC 61131-3.
- Codesys Control: PLC target software for embedded and PC-based controllers.
- Codesys HMI, Codesys Target Visualization, Codesys Web Visualization: Software add-on packages for creating display masks on different platforms.
- Codesys Softmotion: Tool-kit for motion control, which can optionally be integrated into the Codesys Control runtime system. A PLCopen motion control library is also pat of the tool-kit.
- Codesys Professional Developer Edition: Provides additional tools for programmers to be used for high-level programming.
- Codesys Application Composer: Tool for machine and plant builders, who want assembling their applications on the base of pre-defined modules instead of programming them.
- Codesys Safety: The TÜV-certified PLC runtime software compliant to IEC 61508 (SIL 2) is under development, and will include a CANopen Safety option.

have a profound knowledge of the structure and the process of machines or plants but do not know how to program.

> *We have system partners and distributors supporting OEM customers and end-users.*
>
> *Manfred Werner*

The software supplier has established a worldwide representation by system partners and distributors. It is represented through their own office in China and distributors in 15 countries and supports its customers by 22 system partners, which offer consulting services. The company also organizes several events to update OEM customers and end-users. Recently, a distributor in Israel has been appointed: Dor Drive Systems specialized in motion control and renewable energy systems will take over the sales of all Codesys products, will offer trainings, and will organize trade shows as well as customer events. In the Netherlands, Humiq Advanced Software has joined the system partner network. The Dutch company will provide technical consulting as well as support for application development and system integration. ◄

Detecting CAN nodes with different or drifting bit-rates

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Link
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Introduction

If one or more devices in a CAN network use different bit-rates as the others, it is hard to find them. The same problem occurs, if the bit-rates are drifting in one or more devices. In order to detect such "bad boys" and other error-causing nodes , the authors present a method based on evaluating the signal characteristics like a fingerprint.

Reference

This article is based on the paper "New methods for the analysis of the physical layer of CAN networks and possibilities for robustness improvement" by the same authors held on the 13th iCC in Hambach Castle (Germany) in March 2012. It can be downloaded from the CiA website (www.can-cia-org).

CAN network systems in which one or more devices use another bit-rate as the rest of the system, are often caused by new installed or replaced devices. Sometimes the bit-rate setting was misconfigured or has been simply forgotten. It may also be due to faulty configurations on devices using soft-configuration, e.g. using LMT or LSS services as specified by CiA. Detecting a globally misconfigured bit-rate can easily be done using most CAN-monitoring tools with included bit-rate auto-detection or an oscilloscope.

However, common CAN monitoring tools fail, when several bit-rates are used in a single network, as these only check for a valid bit-rate. As soon as one valid bit-rate is detected, the tools normally stop auto-detection and provide the first found bit-rate as the correct one.

When a single device is set to another bit-rate, whilst all other devices are using the defined bit-rate, the failure scenario depends on the used higher-layer protocol respectively the application software. In CANopen for example, all device start sending after initialization their Boot-up messages. Depending on several factors, including bus-load, location of nodes on the bus media and difference of the bit-rates used, the CAN network might work or may also fail immediately or after specific operation duration. At least the node with the faulty bit-rate will not be able to communicate with other nodes. Correspondingly, it will not be visible to the other nodes. Therefore, this node is effectively missing even though it is attached to the network.

As an example: In a network with a limited number of nodes, low busload (less than 20%) and significantly different bitrates, the main system (the nodes operating at the correct bit rate) will work. Assuming an existing system controller does not stop the system as one device is missing or the application software stops node due to missing data. All devices operating at the same bit-rate will work. But the single device with a faulty bit-rate will either:

- Enter error passive state due to the absence of an acknowledgement – it continuously repeats this message until it either gets an acknowledgement or until it goes into bus-off due to other errors.
- Enter bus-off state as its and other CAN-frames are destroyed due to the different bitrates.

For networks with high bus-loads, significantly more CAN-frames will be destroyed; therefore the probability of restarting CAN-nodes is high.

If multiple devices are configured with a differ-

▷

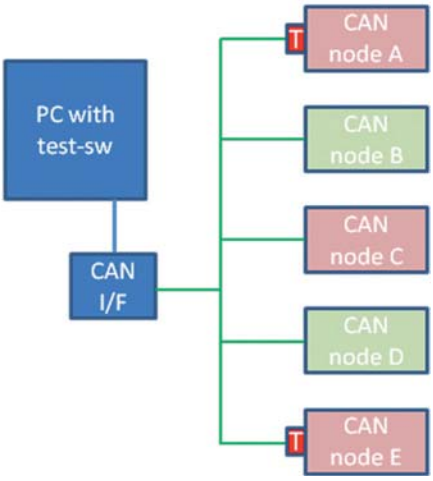

Figure 1: Multiple devices with different bit-rates

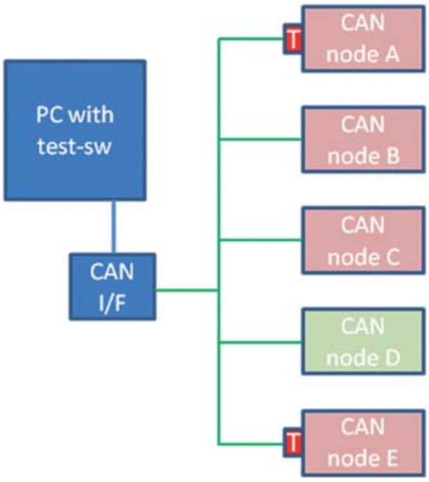

Figure 2: Singe device with a different bit-rate

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Weight	650 g		
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DC power supply	6 V – 32 V		
Power input (@ 24 V - Model 5102)	ø 140 mA / max. 500 mA		
Memory: Program / Configuration / Data	384 kB / 4 MB / 512 kB		
Real-time clock with backup capacitor	Backup time 24 h (typical @ 25 °C)		
Status LEDs (2 colors)	3	4	
Interfaces/Protocols			
CAN	1 (ISO 11898-2 high speed, 2.0 A/B)		
GSM / GPRS (class 10) quad band	850 / 900 / 1800 / 1900 MHz		
GPS tracking capability / accuracy	-	22 channels / 3 m	
CANopen®, Layer 2	✓		
Input / Output	-		2x analog / 2x digital
Software			
RM System Tools	157 002 059		
Configuration license	259 000 101	259 000 100	259 000 116
Product Number			
CANlink® GSM	253 004 028	253 004 027	253 004 032
Certifications			
CANlink® GSM	CE, FCC, E1		

For more details please visit proemion.com

Construction Industry

Transport & Logistics

Agriculture & Forestry

Rail Traffic

CANlink® UMTS

High-speed data transmission via 3G/HSDPA

Transmitting CAN data via 3G/HSDPA has one major advantage: The high transmission speed. If you combine CANlink UMTS with Proemion solutions you can manage and monitor your machines regardless of the distance between you – fast and easily.

Choose your hardware from two CANlink UMTS models, available with GPS functionality and I/Os. No matter which one you decide on: You can always be sure to have the best and fastest connection to your machine or vehicle.

Optimally suitable for

- All kinds of mobile and stationary CAN bus systems
- Applications which require fast data transfer rates and reduced latency

Mechanical Data	5201 A1 · A2	5302 A1 · A2
Dimensions width / height / depth [mm]	126 / 120.5 / 42	126 / 128 / 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 - Model 5302)	ø 80 mA / max. 140 mA (UMTS mode)	
Memory: Program / Configuration / Data	384 kB / 4 MB / 512 kB	
Real-time clock with backup capacitor	Backup time 24 h (typical @ 25 °C)	
Status LEDs (2 colors)	3	4
Interfaces/Protocols		
CAN	1 (ISO 11898-2 high speed, 2.0 A/B)	
GSM / GPRS / EDGE (class 12)	A1: 850 / 900 / 1800 MHz · A2: 850 / 900 / 1800 / 1900 MHz	
UMTS / HSDPA dual band	A1: 900 / 2100 MHz · A2: 850 / 1900 MHz	
GPS tracking capability / accuracy	-	22 channels / 3 m
CANopen®, Layer 2	✓	
Input / Output	-	2x analog / 2x digital
Software		
RM System Tools	157 002 059	
Configuration license	259 000 102	259 000 118
Product Number		
CANlink® UMTS	A1: 253 004 029 · A2: 253 004 040	A1: 253 004 037 · A2: 253 004 038
Certifications		
CANlink® UMTS	A1: CE, E1 · A2: FCC	

* Area 1 (Europe,…) / Area 2 (USA,…): frequency depending on country

Shipping

Mining

Automation

Equipment Leasing

Material Handling

ALL FROM ONE SOURCE

Hardware and Software

The hardware is installed in your machine or vehicle and will reliably transmit data via GSM/GPRS/EDGE/3G/HSDPA. On the software side, Proemion offers the possibility to either display and monitor CAN data with Proemion Web Portal or to access them with Proemion Real-Time.

Proemion offers

- A complete package for telematics
- Easy integration
- Outstanding usability
- Highest system availability

The interaction between hardware and software is a decisive factor for a successful telematics solution. Therefore, Proemion trusts in hardware products which are optimally suitable for all its solutions: CANlink GSM / UMTS.

Many international clients already use the powerful combination of CANlink GSM / UMTS devices and Proemion successfully. They also benefit from the expert support and comprehensive web hosting which Proemion offers.
Just let us know your needs and try the numerous possibilities of Proemion today!

Add-Ons

Proemion Web Portal already offers a sophisticated range of functions in the standard version. However, you can extend the functionality with different add-ons at any time.

Theft protection via geofencing, administration of users, groups and rights, remote diagnostics or notifications on specified events – add all these extra functions according to your needs.
That way, you can create your own, customized Proemion Web Portal.

Proemion Real-Time not only allows for real-time access to diagnostic data, but can also be extended with the Proemion Web Portal functionality.

Proemion can offer you the following versatile add-ons:

- Geofencing
- Administration
- Events (SMS/e-mail)
- Display Values
- Additional Values
- Real-Time

SIM Card Handling

Apart from the hardware and software, Proemion can also provide you with SIM cards for the CANlink GSM / UMTS devices and thus deliver the hardware pre-configured and ready-to-start.

The use of this "all-in-one package" ensures that the software, hardware and SIM card are perfectly adjusted and allow for an optimal use in your machine or vehicle.

Best of 2012 Award

Proemion Real-Time has been honored with the "Best of 2012" award by an expert jury of "Initiative Mittelstand". This initiative is in charge of a well-known German innovation award for medium-sized businesses and states with the "Best of 2012" award that Proemion Real-Time is one of the top products in the category "Mobile".

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ent bit-rate, this leads to several different bit-rates in the network. If we use the same assumptions as above (low bus-load, significantly different bit-rates, limited amount of nodes and no main system controller stopping the system) the system might work – at least the nodes with same bit-rate will be able to communicate with each other. Nevertheless, there will be a significantly high number of error-frames.

Even if devices are correctly configured, it might happen that devices show a wide-drifting range of their bit-rate. This also leads to temporary different bit-rates and may show similar behavior as described in the case of a single device or several devices using faulty set bit-rates.

Detection of different bit-rates

To detect the different bit-rates, several tools may be used:

- Oscilloscope
- CAN service, diagnostic and monitoring tools
- CAN-based host controllers

When using an oscilloscope, a very detailed analysis is possible and also very small bit-rate variations can be measured. This is often the only way of identifying the CAN node with a faulty set bit-rate. However, an oscilloscope is more expensive than the other tools and analysis requires significantly more CAN know-how and effort if a basic oscilloscope without CAN trigger and CAN decode functionality is used.

CAN service tools, whether hand-held stand-alone tools or PC-based solutions, e.g., PC-CAN interface with CAN monitoring software, are commonly used to check the basic operation parameters of CAN networks such as bus-load, active CAN nodes and CAN identifiers. But these tools may also allow a very detailed analysis of the data communication.

Some of these CAN monitoring and test tools provide automatic bit-rate detection, which sets the CAN controller to different bit-rates and selects the bit-rate, which provided valid CAN data frames. This allows to detect different bit-rates.

CAN-based host controllers can also be equipped with this bit-rate scan mechanism.

As we will focus on the user-view, we will only explain the possibilities, when using CAN test tools and will omit the usage of oscilloscopes. We will also omit the host-controller, as the results are identical to the results when using CAN test tools.

With some modifications by the tool providers, it is possible to enable checking for several simultaneously used bit-rates in a CAN network. To verify the operation and reliability of this idea, we generated a prototype test software. The automatic bit-rate detection of our CANopen Device Manager was used as a basis for this test software. The test software interacts with a CAN controller scanning for common bit-rates, including the bit-rates as specified for CANopen networks. Scanning is done by setting the CAN controller to a bit-rate and checking, if valid CAN frames are received within a pre-defined check time. If valid CAN frames are received, the selected bit-rate is included in the list of active bit-rates. After expiration of the check time, the CAN controller is set to the next bit-rate to be tested. To make sure that the check time does not fall into the restart time of a CAN-node going into bus-off, the complete scan procedure was repeated.

A PC-CAN interface using a standard SJA1000 CAN stand-alone controller by NXP was used. In addition, the test setup included the modified monitoring tool with bit-rate-detection and a CAN network consisting of five CAN nodes as shown in Figure 1. The termination resistors are attached to nodes A and E.

Nodes A, C and E use bit-rate 125 kbit/s, the nodes B and D are configured to communicate with 250 kbit/s.

After running the automatic bit-rate detection, the test software shows both used bit-rates. Several CAN test tools used for comparison show only the first found bit-rate depending on the implementation of the bit-rate detection.

Using the CanAnalyser set to the found bit-rates provides information on which nodes are using which bit-rate. This allows detecting the faulty configured devices.

If just device D communicates with 250 kbit/s (see Figure 2), the tools may also detect only one bit-rate as in the above described scenario with multiple misconfigured nodes.

If all nodes are configured to use 125 kbit/s, and node D is modified in a way to achieve a wide range drift of the bit-rate, the error rate shown in a simultaneously running CanAnalyser was lower than expected. The explanation for this is that the drift was not big enough to get close enough to other bit-rates. This was proven using an oscilloscope. Therefore, the test-software would need to use all bit-rates supported by the CAN controller, then setting the CanAnalyser set to all active bit-rates would show node D using several bit-rates.

Detecting the sources of error-frames

The CAN protocol is focused on providing robust communication independent from external influences. Therefore, CAN makes use of advanced error detection, error notification and error containment mechanisms, which are included in the protocol-engine of each node.

The only way to get more information on the node, which started the error-flag is using an oscilloscope. However, even with this, it is often not possible to identify the causing CAN node.

If passive error flags are visible on the oscilloscope, then the node transmitting this current CAN frame is destroying it. Therefore the CAN identifier can be used to select the causing device. However, in certain cases this does not help, e.g. if CAN remote frame, is destroyed.

For active error flags or in case of not possible detection using the above way, the oscilloscope can help detect the culprit. With oscilloscopes offering better bandwidth, higher sample rates and easy to use mask tests, it is also possible to detect the CAN node causing the error by only the starting edge of the error flag.

The allocation of a message due to a single signal edge is only possible if the signals from the different nodes differ to a certain extend. The signal difference is due to:

- Different layout and components used in devices, notably protection circuits have major impact on the signal form.
- Variances in components even in identical built nodes can cause the signal form to differ. Differences in resistors and capacitors lead to different signal levels (e.g. due to changing power supply of CAN transceiver, changing capacitance/impedance, etc.).
- Differences in voltage-supply and local EMI. If the power supply of the node is affected and offers inconsistent voltage levels, this can have ef- ▷

fects on the CAN node (depending on node design), the same is true for disturbances that are on the voltage line and might affect devices via this way.

- The position on network cable also influence the signals, the signal form of distant devices differs from nodes close to the measurement device, even if the devices would have identical signal forms if connected directly to the measurement device.
- The position regarding other CAN nodes in a CAN network also affects the signal form significantly. CAN side local EMI effects do influence the signals significantly – and these EMI might also be due to specific CAN nodes, e.g., high power inverters.

To show the difference in signals, two nodes of the same making in an optimized laboratory network (10 m cable length, minimum external signal distortions and a 1 m distance for node B and a 9 m distance for node A to the oscilloscope) are measured (see Figure 3). It is easily possible to distinguish messages from different nodes by only one single signal edge as shown in Figures 4 to 6. To achieve this view a mid-range oscilloscope was used, with an external trigger on the recessive dominant signal edge. Each graph shows a timeline of 60 ns at a bit-rate of 500 kbit/s.

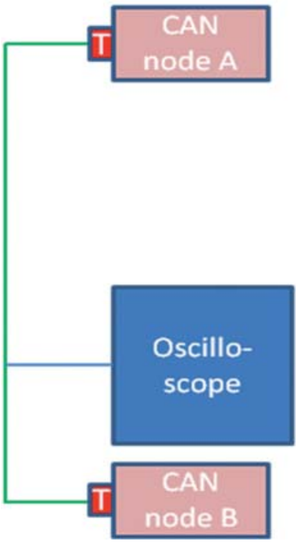


Figure 3: Test setup for node detection according to signal characteristics

Generating a signal-database

First, it is necessary to get each node's signal measured. Notably, the signal edge recessive-dominant is important. To get good results, the network should show the same behavior as during standard operation otherwise signals will look too different for good allocation to the different nodes.

When measuring, the oscilloscope needs to be triggered to the specific messages from the different nodes or it is necessary to verify that only the specific node to be measured is transmitting. Note that detaching other nodes from the network is not good, as this will also influence the CAN-signals.

Therefore a mid-range oscilloscope with internal or external CAN trigger capabilities should be used. Whether this signal is measured and stored by an oscilloscope or a PC-based tool with external sampling hardware is not relevant to the measurements. Either way, it is recommended that the used oscilloscope or sampling hardware should provide a bandwidth and sampling rate of more than 500 MHz. For basic CAN-analysis a lower-performance oscilloscope is suitable, but due to the fact that only a single edge needs to be analyzed in detail, a limited sampling performance will give poor results and it will be hard to identify the error generating CAN node. In addition, oscilloscopes with integrated mask generation and mask tests will ease the comparison of the different signals measured.

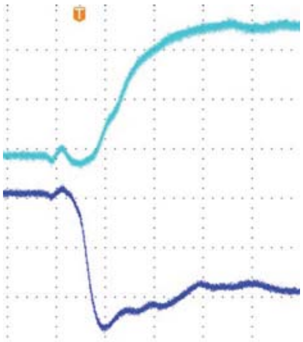


Figure 4: Node A (purple: CAN-low; blue: CAN-high)

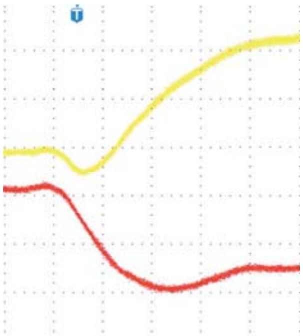


Figure 5: Node B (red: CAN-low; yellow: CAN-high)

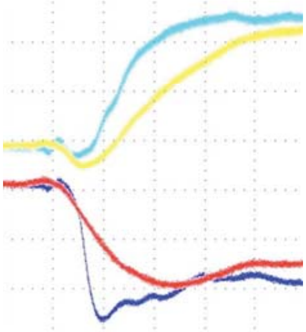


Figure 6: Node A (purple: CAN-low; blue: CAN-high) and node B (red: CAN-low; yellow: CAN-high) in overlay

The easiest way to get this special signal edge from all nodes is to measure all messages in normal operation mode for a certain time. The oscilloscope should decode the Identifier of the messages and store the signal information to generate a kind of "signal database" for the checked CAN-network. With all nodes being measured, signal information can be stored in the oscilloscope's memory.

This stored information now allows determining all messages transmitted by one single node by comparing the sampled signals. By verification of this message, signal-to-node assignment, the user can also check the quality of scan.

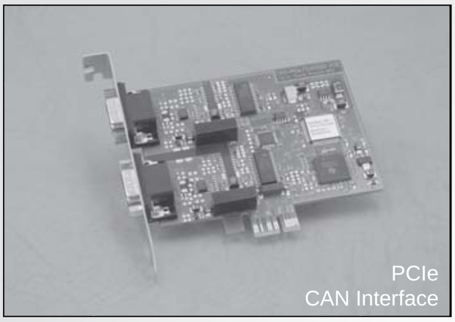
In addition, the questioned error flag should be sampled using the same oscilloscope and same settings. Notably, the signal edge recessive/dominant is important.

Now this sample is to be used to generate a signal mask, and by reloading the single node signal samples, it is possible to determine the best fitting signal. As this best fitting signal is calculated from the similarity of the signal masks, the quality of this solution could be calculated in fitting percent.

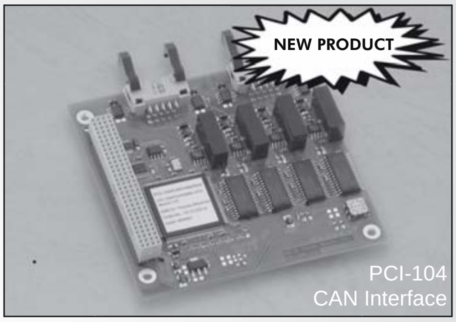
If the fitting percentage is high, then the sender of the error flag seems to be found. If the fitting percentage is low or if the measurement system is not able to find a node that fits, then the following might be cause:

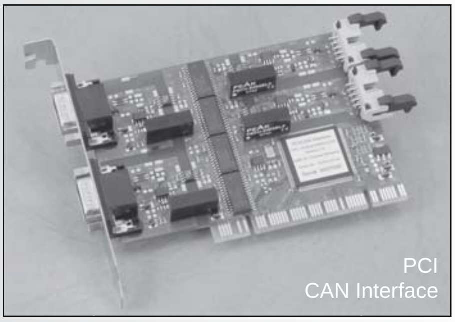
- Several sent an error flag at the very same time due to detection of message data errors
- Other physical effects cause a global CAN failure, which results in all nodes starting the error flag.

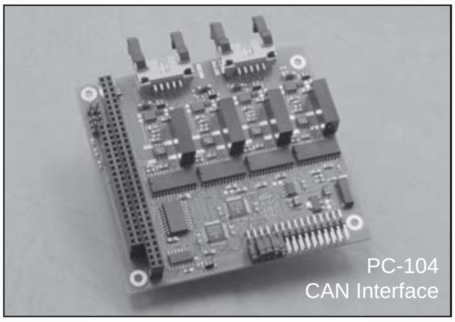
In this case, the transmitting node as well as the physical characteristics of the CAN network need be examined in detail. The available signal samples and the complete sampled CAN error message will also help to find the reason of the error. In order to examine the node transmitting, the "destroyed" message either by checking the CAN-ID, or if the CAN-ID is destroyed or possibly used by several nodes (e.g. for CAN remote frames) by using the sampled signal edge of the data field for comparison with the already available "signal database". ◀


PCIe
CAN Interface


USB/CAN Interface
CPC-USB/ARM7-GTI
Version 1.0
Serial 0000001
EMS Dr. Thomas Wünsche
USB
CAN Interface


NEW PRODUCT
PCI-104
CAN Interface


PCI
CAN Interface


PC-104
CAN Interface


EtherCAN CI-ARM7/RMD
EMS Dr. Thomas Wünsche
Ethernet
CAN Interface


CE
LIPOWSKY
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GND LIN VCC
RUN ERROR

Finding CAN communication faults before they happen

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CAN-to-USB interface

The Leaf Light interface module connects the CAN network to a mobile equipment such as PCs or iPhones. The CAN side supports bit-rates up to 1 Mbit/s. The 100-g module does not loose CAN messages to be received or to be transmitted. The time-stamp precision is specified as 100 µs. The power consumption is 70 mA.

CAN communication fault finding in modern cars is a highly precise science, if the work of Systems & Advanced Technologies Engineering (SATE) is anything to go by. The Italian company is specialized in the simulation and fault diagnosis of machinery and plant, with automotive systems being a key market. One of its key customers is a well-known Italian luxury car manufacturer, which has used the company's software and consultancy services to diagnose incipient breakdowns in car prototypes during endurance testing.

The company creates a simulated model of a system, using data from the CAN network to generate algorithms that monitor the devices and predict faults, as well as the impact of wear and tear. The simulations use either 'transparent box' models that base their analysis on the physical laws governing a system's interactions, or 'black box' models. The latter are algorithm-based, created using neural networks that are 'trained' on a set of real world input and output signals.

Whichever type of simulation model is involved, highly-accurate signal logging from the vehicle's CAN network is needed in order to develop and then implement the model e.g. during the training phase in the case of black-box models or parameter tuning for transparent box models. During algorithm training or tuning, signals are logged on the system under normal conditions. Any mismatch between the model's output and the real-world corresponding quantity implies a fault or an evolving anomaly, such as engine lubrication issues, problems within the cooling system, alternator, clutch or gearbox.

An important benefit of using an algorithmic approach for faultfinding is that there is no need for additional sensors on the CAN network, which can be a source of potential failures, aside from those already present. So in the case of a vehicle, its already-interconnected ECUs will be able to provide enough information about the components and subsystems to give a picture of the reliability and lifetime of the whole car.

A vehicle has three main sources of sensor-based information: vehicle kinematics (speed, acceleration), engine operation (rotation per minute, water temperature), and driver control actions (steering wheel angle, brake, accelerator pedal position). From these parameters (i.e. without adding more sensors), information such as tire pressure and temperature can be estimated using the Italian company's models. Among the conditions this method is capable of detecting are sensorless tire deflation, driver behavior and anomalous driving pattern detection, gearshift classification and synchronizer diagnostics. SATE's algorithms have also been used to accurately predict small

▷

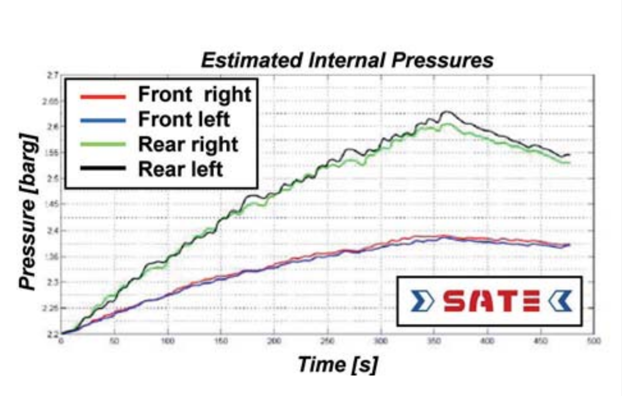
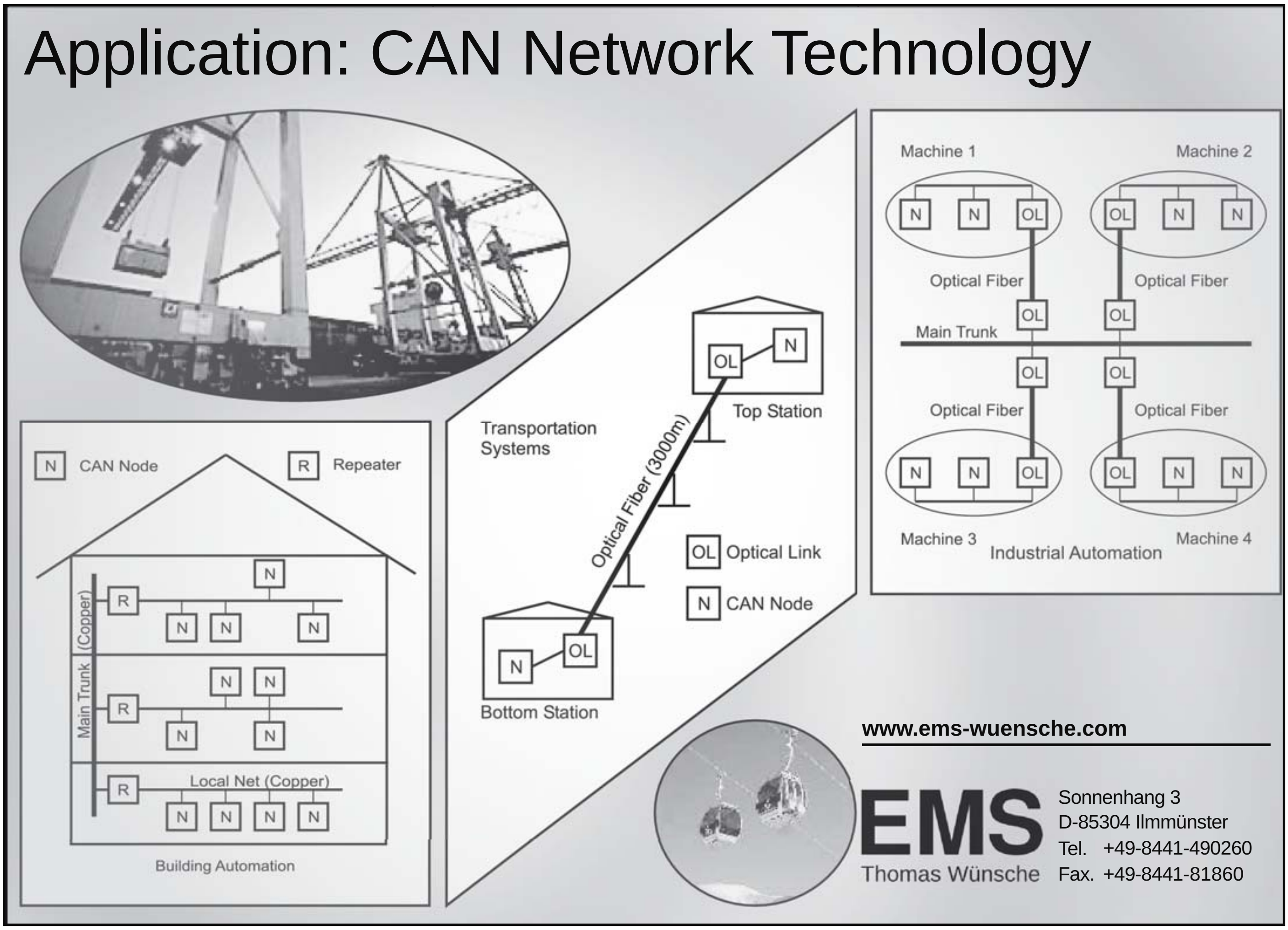


Figure 1: Simulated and estimated tire pressures


Application: CAN Network Technology
N CAN Node
R Repeater
Main Trunk (Copper)
Local Net (Copper)
Building Automation
Transportation Systems
Optical Fiber (3000m)
Top Station
Bottom Station
OL Optical Link
N CAN Node
Machine 1
Machine 2
Machine 3
Machine 4
Optical Fiber
Main Trunk
Industrial Automation

Conclusion

With these low-cost mobile computing options, from mobile PCs to iPhones, the advanced predictive diagnostic solutions – connected via Kvaser's CAN-to-USB or CAN-to-wireless interfaces – have the potential to be applied to a much wider range of end applications than previously. Where once this kind of dynamic systems modeling was restricted to research and system prototyping applications, it can now be applied to road-going cars, trucks, machinery and plant, to provide early-warning information for fleet managers and maintenance teams. This type of information is also proving beneficial to OEMs that are responsible for providing long-term warranties or full life support of their equipment. And, with CAN network technology found in so many applications beyond the automotive sector, it is no surprise to hear that the software and service provider is applying its simulation expertise to fields as diverse as marine and underwater systems, energy generation, and oil and gas.

leakages or control anomalies in the engine coolant system, where early detection can prevent potentially severe damage to the motor. Another example is the detection of insufficient oil pressure, whilst it was still within the regular range. In the latter case, SATE provided Ferrari with a warning of this as early as 5000 to 11000 km before engine break down, and well before a test driver could detect it.

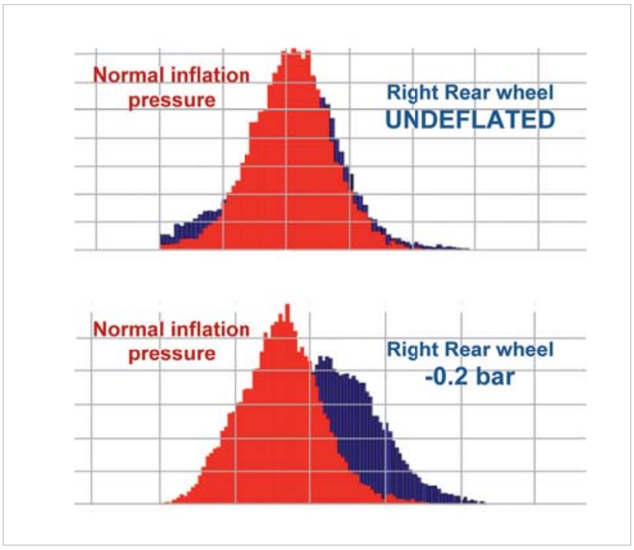


Figure 2: Tire pressure and temperature sensorless monitoring

The Italian company uses the Leaf Light CAN-to-USB interface by Kvaser (Sweden) to connect to the vehicle CAN network, design on-board diagnostic systems and deploy prototype demonstration applications, such as the smart fuel consumption monitoring application. It was developed for an Hewlett-Packard iPaq for use on trucks. The USB/CAN dongle provides time-accurate and loss free transmission and reception of standard and extended CAN messages, as well as easy connection between any CAN network and commercial devices equipped with USB ports, such as PDAs, mobile PCs or desktop PCs.

At present, the most-commonly employed strategy for fault location by modern vehicle manufacturers is threshold-based signal monitoring, whereby faults are detected when signals exceed a set of thresholds. However, this approach fails to detect incipient faults, which are usually tolerable in the early stages of their development, but which will cause a deterioration of the system performance over time. The model-based strategy effectively sets dynamic residual thresholds, resulting in faults being detected earlier and averting the false alarms that are often associated with a 'threshold-based' method, where excessively narrow or low thresholds have been set. ◀


CAN
Ethernet/CAN Interface
EtherCAN CI-ARM7/RMD
Version 2.1
EMS Dr. Thomas Wünsche
Status 1
Status 2
Status 3
CAN Active
Eth. Active
Eth. Link
Serial


Marine conditions?
BRING IT ON!
CANopen
SAE J1939
ISOBUS
e17
100G
CoDeSys
CE
GL
EPEC
2024 C2.3
1
2
3
4

Simulation of electric aircraft solutions

Werner Brandis

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Link
www.hesch.de

Figure 1: Switch cabinet developed by engineers at Cassidian

Today, hydraulically operated landing gears and actuators, pneumatic air conditioning, electric avionics and mechanical drive trains operate side by side inside all standard aircraft of existence. This diversity of systems causes a high degree of technological complexity, resulting in increased fuel consumption, more frequent and more expensive maintenance and higher energy expenditure. For this reason, intensive international research has been conducted over the past ten years to assess how aircraft can be operated only electrically in the ideal scenario. Worldwide projects for “More Electric Aircraft” (MEA) have the goal of converting as many components as possible to electric actuation.

In the area of civil aviation, initial progress in this direction is apparent in the fact that the Airbus A 380 is the first aircraft to have a thrust reverser that operates electrically, instead of hydraulically or pneumatically as it is usual. Boeing is also going new ways, for example with the 787 “Dreamliner”. Instead of zap air for the air conditioning and deicing systems, two 250-kVA generators (one for each engine) are used, which also power the electric motors for starting the engines. The consistent use of efficient electric systems reduces the on-board power consumption. In addition, load management of the numerous potential consumers allows optimization of the electric loads.

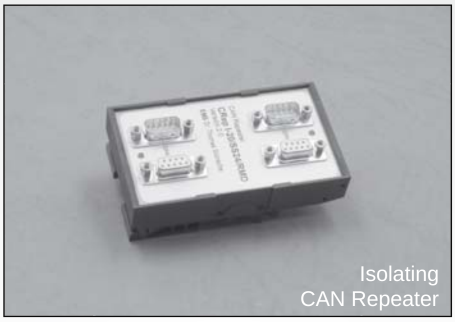
Load simulation

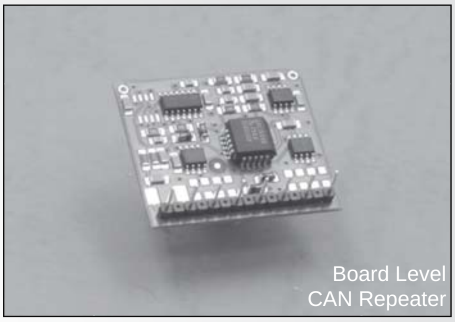
The potential of the MEA development is higher in military aircraft than in civil aviation. Since fighter jets, drones, etc. contain a great deal of technology in a very small space, the use of different energy systems side by side, and therefore with numerous redundant components, has a negative effect in the case of such aircraft. In one MEA project, the engineers at Cassidian (an EADS subsidiary in the German Manching) developed a simulation switch cabinet with four identical 270-V_{DC} channels for simulation of inductive and capacitive loads in the 270-V_{DC} network commonly used for military aircraft. By switching the different R, L and C components on and off, different types of loads are applied to the SSPC (Solid State Power Controller) of a 270-V_{DC} power supply. This allows the simulation of every conceivable operating and load scenario for electric aircraft components, as well as entire systems. The channels are centrally controlled via a CAN network. For process control and monitoring, Cassidian uses the process I/O modules by Hesch Industrie-Elektronik. In addition to the central CAN network controller, the modular simulation system features actuation modules for the individual loads such as digital input modules that monitor the return values. The contactors are controlled separately by relay modules, in order to switch the required input current for the contactors. For each C and L module there are eight condensers or coils, and four load resistors for each load path.

Control and monitoring

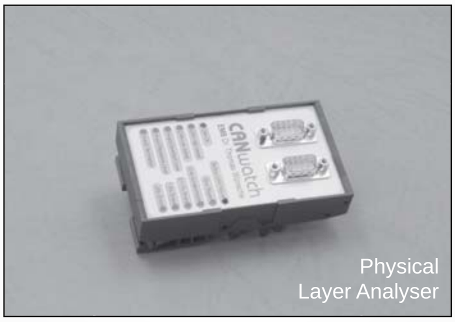
The internal control and monitoring of the system ▷

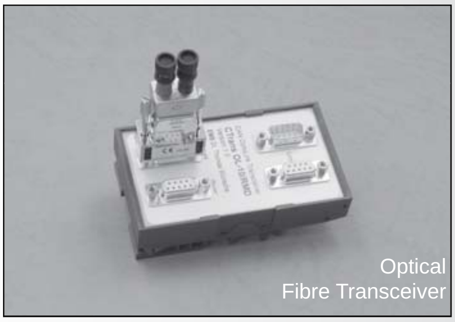

Compact
CAN Repeater


Isolating
CAN Repeater


Board Level
CAN Repeater


Gateway
CAN/CAN


Physical
Layer Analyser


Optical
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Summary

In today’s civil and military aircraft, electric, hydraulic, pneumatic and mechanical actuating components operate side by side. This conglomeration complicates the construction and maintenance of the aircraft. That is why companies and research institutes worldwide are working on projects for “More Electric Aircraft” (MEA), with the goal of converting as many components as possible to electric actuation. For this purpose, the EADS (European Aeronautic Defence and Space) subsidiary Cassidian developed a 270-V_{DC} CAN-connected overall system rig, which allows engineers to simulate the possible electric loads in aircraft. Since the engineers did not have all of the electric consumers at their disposal, Cassidian also developed a switch cabinet that simulates these consumers. The cabinet is equipped with CAN-capable process I/O modules from Hesch Industrie-Elektronik (Germany).

Company background

In addition to the production of automation components such as the IMOD I/O system, Hesch is also specialized in the development and manufacturing of customized hard- and software solutions. For more than 30 years the company has developed and produced analog and digital measuring and control instruments, electronic controllers, sensors and transducers.

Further to individually developed products and systems, the manufacturer offers production facilities in an SMD assembly line. The portfolio also includes measuring instruments, controllers and switch cabinets for the cleaning of industrial filter systems.

Figure 2: “Hot swap” exchange of devices

Figure 3: Digital input modules HE 5820 and HE 5822

load simulations in the switch cabinet is achieved with the I/O modules. The CANopen field bus coupler HE 5811 connects the control cabinet with the CAN network, controlling up to 64 modules and supplying up to 16 of those modules with electric power. Together with the power module HE 5850 for 16 additional I/O modules, all control devices are power supplied without additional wiring. For the control of the loads, Cassidian used relay output modules HE 5826, which transfer the signals from the network via 4-V free changeover contacts. The digital input modules HE 5820 and HE 5822 monitor eight and four binary return values and transfer them to the CAN network. The modules used in the system provide several configurable functions. This reduced the number of different modules, as well as the costs of acquisition and inventory.

Configuration during operation

For a complex simulation system with high loads, it is important for the modules to feature the “hot swap” function. This makes it possible to exchange single modules at any time, even when the system is in operation. A separate address is assigned to each module through the internal automatic self-configuration by the CAN network coupler. When a module is exchanged, the address and the configuration data of the previous module will be automatically assigned to the new module. The node-ID of the CAN coupler is designed for user-specific configuration with two rotary switches.

In case limit values have to be adapted to the actual operating requirements, system configuration is possible while the system is in operation. Configuration may be done by using the Smart Control software either from a higher-level control unit (PC station) via the CAN network or from a laptop directly via the respective CAN coupler. The corresponding interface is integrated in the front cover of the coupler.

The modules are capable of processing incoming signals internally so that they no longer have to be converted by a higher-level controller. This reduces the computing load of the controller and regulator, which is then available for other applications. Many processes in process technology may therefore be accelerated and streamlined.

Power for the modules is provided by the HPR (high performance rail) line, which is integrated in the standard top hat rail. It consists of several plug-in sockets for a quick module expansion. The HPR connectors are also used for system communication, so the modules do not require additional wires. Module’s functions may be adapted to specific customer applications. For example, the modules feature galvanic insulation and monitoring of short circuits to prevent damage as well as functions for detecting burnouts. Separate components for these functions are not needed. To ensure the reliable control of processes in case of malfunction, the modules continue operating with substitute values. These values are individually configurable, not only to ensure the continuation of the processes, but also to prevent dangerous situations. ◀

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Qseven can CANopen

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Introduction
Fast and flexible CANopen-based systems for industrial automation, transportation applications and modern energy facilities may be implemented on the basis of compact Qseven embedded modules with integrated CAN controller. MSC (Germany), in cooperation with Ixxat (Germany), offer in-house developed processor modules as well as complete CANopen solutions.

MSC entered into a partnership with Ixxat Automation in order to offer the CAN-connectivity while software and hardware integration in industrial applications. In addition to embedded modules, the scope of delivery includes the device driver and the CANopen protocol support so that customers are able to implement systems at a higher application layer. According to Wolfgang Eisenbarth, CANopen support on a Qseven processor module with industry-standard CAN components is finally realized thanks to the intensive cooperation of the two companies.

The fields of application for CANopen-based systems range from industrial automation, laboratory automation and healthcare technology to transportation applications (rail vehicle technology and vehicle equipment such as for the police, fire department and construction machines) and elevator systems, to name just a few examples for which Qseven modules are suitable. A number of promising applications in modern energy facilities such as solar and wind technology, in building automation and in smart grid solutions are also conceivable. First projects are underway.

Originally developed as an in-vehicle network, CAN established itself as a standard embedded network for various control systems. In addition to the reliable communication system, the flexible configuration options and interoperability of the individual devices are the main focuses for developers of embedded networks. Hence, the CAN-based higher-layer protocol CANopen as well as a large number of CANopen specifications were developed by the CAN in Automation (CiA) organization. The goal is to open up CANopen networks also to small and medium-sized users. In addition to the CANopen application layer and communication profile (as defined in CiA 301), the CANopen specifications include a framework for programmable CANopen devices (CiA 302), CANopen cabling and connector pin assignment and CANopen representation of SI units and prefixes (CiA 303 series). CANopen device and application profiles (CiA 4xx documents) are dedicated for according devices or areas of applications. Up to now, CiA has allocated almost thousand of CANopen Vendor-IDs. Numerous companies already offer a wide range of standard products, tools and protocol stacks.

Embedded modules

The provision for CANopen support on a compact embedded module in the Qseven form factor was created with the expanded and revised Qseven specification revision 1.2. One of the updated features is the support for CAN and UART functionality and the

Figure 1: The Q7-TCTC-FD platform (MSC)

Figure 2: The Q7-MB-EP3 baseboard (MSC)

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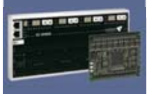

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support for x86 und ARM/RISC processors on the same carrier board. The MSC Q7-TCTC-FD platform is company's first x86-Qseven module with the CAN controller already integrated in the chipset. The module comes with an Intel Atom E6xx processor series that supports hyperthreading and Intel's virtualization technology in some options. The module family is offered in four different computing performance variations. The entry-level model integrates the 600-MHz Intel Atom E620 CPU and has a TDP (thermal design power) of 2,7 W. Alternatively, computer-on-modules are available based on the 1,9-GHz E640 CPU, the 1,3-GHz E660 CPU or the 1,6-GHz E680 CPU with a TDP of 3,9 W. The modules providing extended temperature range of -40 °C to +85 °C are offered as well.

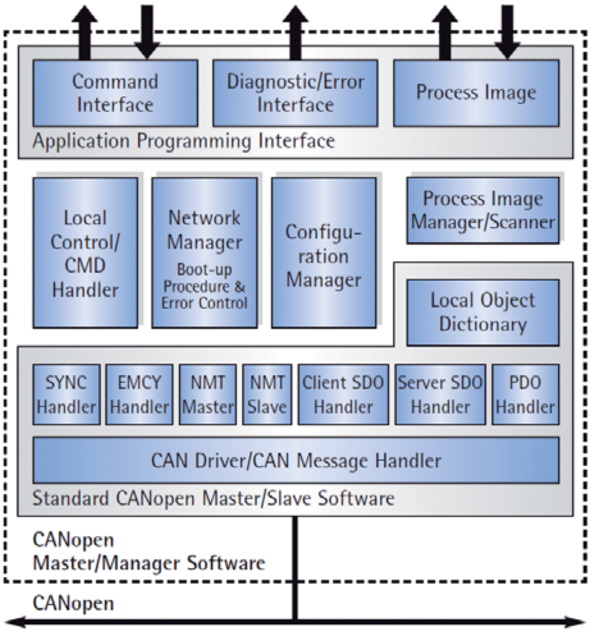

Figure 3: The modular CANopen Manager software (Ixxat)

In addition to a 32-bit single-channel memory controller, an Intel GMA (graphics media accelerator) 600 is also integrated in the processor. The 2D/3D-capable graphics engine runs at 400 MHz and uses a video memory with a capacity of up to 384 MiB. The GMA supports acceleration of video playback with HD resolution by hardware Mpeg2 and Mpeg4 decoding as well as encoding of videos. The Intel EG20 platform controller hub (PCH) is connected directly to the processor via one of the four PCI Express lanes. The board contains a 1-GiB DDR2-533 SDRAM. The module contains an ACPI 3.0 power management with suspend-to-RAM support and integrated functions for battery management, watchdog and system monitoring. In addition to CAN, the Qseven platform offers six USB host and one USB client ports, three PCI Express lanes for customer-specific extensions, LPC (low pin count bus), audio interface and a 10/100/1000 Base-TX Ethernet. SD cards may be connected via the SDIO interface. The system may be enhanced with a 4-GiB or 8-GiB flash memory connected via the Sata II interface. An LVDS (18-bit/24-bit; up to 1280 x 768 pixels) interface and a SVDO interface (up to 1920 x 1080 pixels) are provided for connecting a display. In the dual mode two displays may be driven simultaneously.

The MSC Q7-MB-EP3 baseboard is dedicated for implementation of embedded systems based on the Q7-TCTC-FD Qseven module family. It is provided with assembly options for the commercial and for the extended temperature range. The module is mounted onto the baseboard through an MXM connector. Wolfgang Eisenbarth explains: "The flexible baseboard saves extensive in-house development costs for customers. In order to optimize their system, customers can, of course, develop their own baseboard with the desired functionality and required interfaces. In our demonstration kit, we have used a H1-A compact DIN rail-mounted PC from DSM Computer, which integrates our Qseven processor module. In our demo set-up, the CAN bus is routed from the industrial PC to an off-the-shelf industrial terminal (for example, from Beckhoff) and to a CAN gateway from Ixxat, which offers analog and digital interfaces for the process connection. Thus, numerous CAN devices and CAN modules such as sensors and actuators can be connected."

CAN gateway

The CANio 500 I/O gateway from Ixxat enables connection of analog and digital signals to the CAN or CANopen network. The respectively four configurable analog inputs and outputs offer a resolution of 12 bits. The analog inputs are available in different voltage ranges with differential input circuits or current inputs. Four digital inputs and outputs are available as well. The voltage range of the short-circuit-protected outputs is selectable. The switching threshold of the inputs automatically adjusts to the selected voltage range. In order to ensure operability in both CANopen and CAN systems, the device is designed as a self-starting CANopen NMT slave, in which all important parameters, such as node-ID or sampling rates of the analog inputs, are stored as default values. This enables the device to start its operation directly after startup, also without making any further settings. The individual configuration of the gateway for different applications may be done either by loading configuration data by a CANopen NMT master or by sending configuration messages in a CAN network. It also may be done offline via the configuration tool for the gateway.

CANopen software

The CANopen Manager software by Ixxat acts as a network manager and as a configuration tool for CANopen networks. Built on the core elements of the CANopen protocol, the manager software supports the network startup procedure as defined in CiA 302 additional application layer functions specification for CANopen. The software enables the implementation of a CANopen controller-based device configurable according to the given network topology. It is suited for the integration with IEC 61131-3 run-time environments by providing a built-in process image manager for the data exchange with a host system. The software is also usable for Ethernet-to-CANopen gateways, in which the device acts as an I/O device or a slave within the Ethernet network and as an NMT master in the CANopen network. Other fields of application are HMI systems, which operate either as CANopen NMT slave or as NMT master. The CANopen Manager supports no further CANopen device and application profiles. ◀

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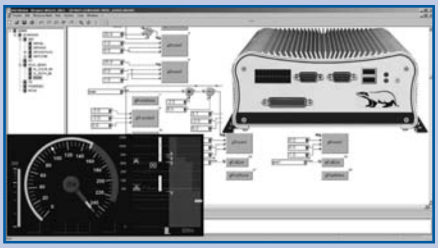

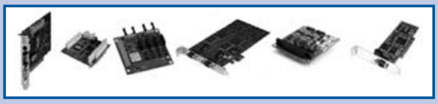

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Introduction

Today, CAN, extensively used in automotive designs, gained acceptance in industrial automation, medical equipment, vending machines and other embedded system networking applications. Thus, a growing number of engineers are being faced with the task of implementing CAN-based solutions. For networked embedded system applications that require reliable communication and good noise immunity, CAN technology is a robust alternative to EIA-232/-422/-485, I^2C and SPI serial interface links. Therefore Renesas provides the RX micro-controllers (MCUs) for CAN-based designs ranging from low-end to high-end flash-based CAN controllers with automated fault detection with correction capabilities.

The CAN interface may be used with an easy accessible CAN API (application programming interface) programming layer. Coupled with the fact that the CAN peripherals execute the low-level protocol work, Renesas employees mean that CAN is very easy to use and enables a fast implementation for your application. This article provides technical introduction in a possible CAN usage case and shows details about CAN's ability to provide low latency, flexible routing of messages and error handling.

CAN controller take care of the low level transmit and receive details enabling the programmer to concentrate on the application. The main focus for the application and programmer is the mailbox, also known as "message box", "buffer" or "slot". When an API is used, the mailbox is the point of bus interaction. The more mailboxes are provided the greater is the design flexibility for the application developer. Also the peripheral will need less runtime for reconfiguration.

Using the mailbox, an application developer may only read/write the CAN-ID, data length code (DLC), and the data fields (and a timestamp if used) of a CAN message, as the application software reads/writes only these fields. Table 1 shows the required interaction with a mailbox when configuring it to communicate. After configuration, the hardware layer takes care of the

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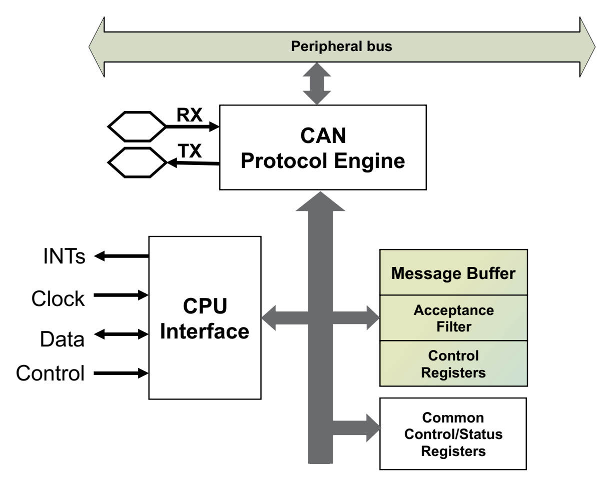
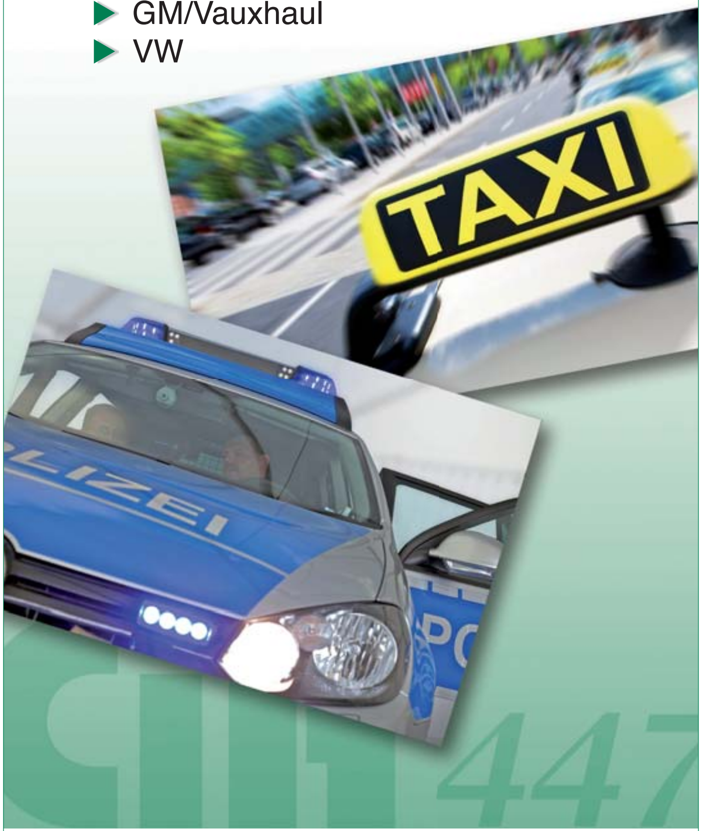


Figure 1: RX600 CAN interface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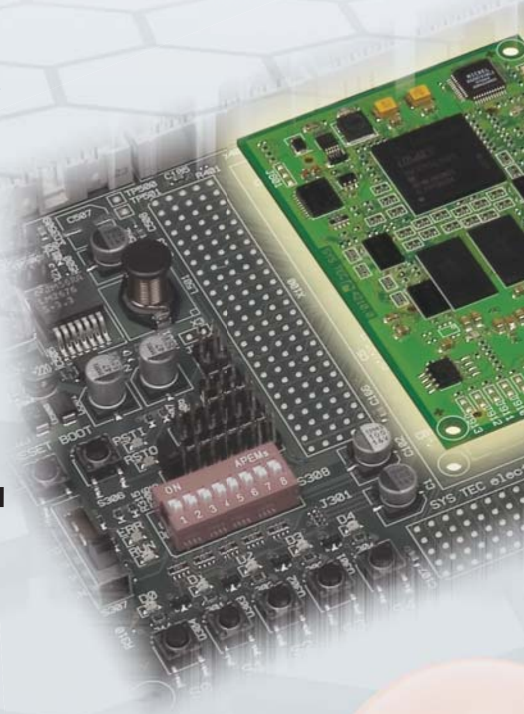

Field	Transmit	Receive (mailbox setup)	Receive (get message)
ID	Write	Write	Read
DLC	Write	-	Read
Data	Write	-	Read

Table 1: Required interaction with the mailboxes

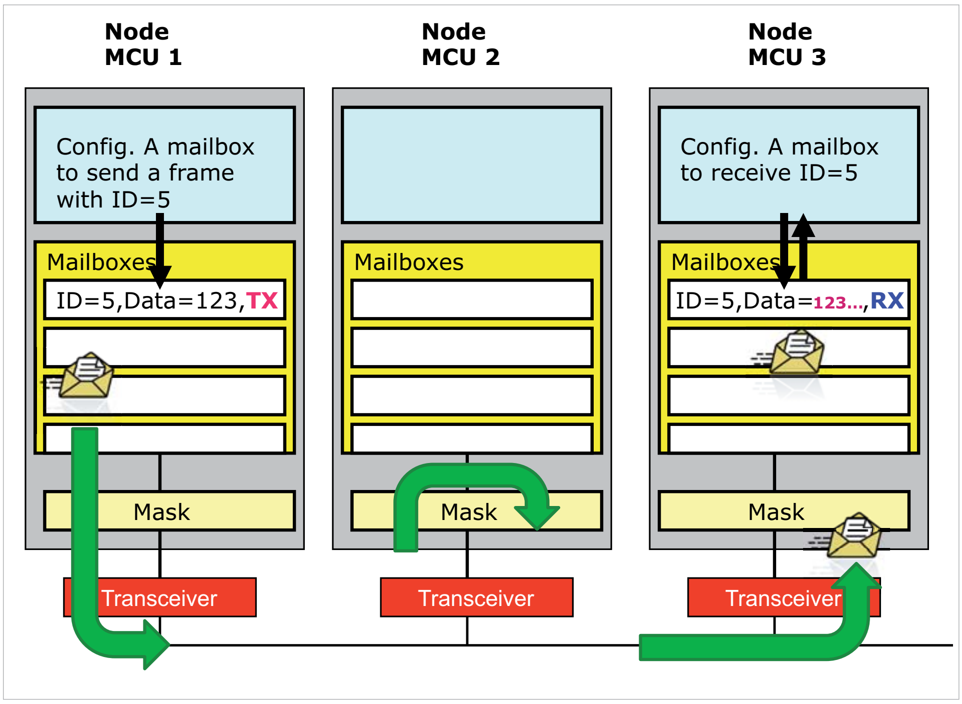

Figure 2: Communication process in a network with three nodes

rest. The transmitter mailbox will manage the low-level transmit details and on the receiver side the mailbox hardware only captures messages with the set CAN-ID. It should be noted that a reconfiguration of the mailbox could also be done during run-time.

Figure 2 illustrates the basic data flow process in a communication network where three CAN nodes are used. Node 1 is sending a message with the CAN-ID of 5. Since node 3 does have a previous setup of their mailboxes to accept messages with the CAN-ID of 5, node 3 accepts the message. Node 2, where no prior setup of mailbox has been done would not accept this message. Renesas's RX MCU does offer up to 32 mailboxes for each CAN interface. Thus, it is capable to receive 32 different messages with different CAN-IDs. It should be noted that all messages are broadcast and received by all participants on the bus. All nodes check the CRC (cyclic redundancy check) sum and then check if any mailbox is configured to receive the sent CAN-ID. If this is true, the received message is copied to the mailbox of a CAN node.

The CAN API

In a layered model, the CAN peripherals control and the CAN API would be placed above the two lower ISO/OSI layers (CAN physical and data link layer). What it required to initialize the CAN peripherals? Setting the CAN operation mode to reset/initialization, enabling the CAN ports, setting the operating mode, setting bit timing and bit-rate and setting the mask registers for acceptance filtering. The procedure for enabling the CAN interrupts followed by setting of a mailbox for send or receive, fetching data from a mailbox etc. should be considered as well. The

▷

The RX600 platform

With up to 128 KiB of RAM and up to 2-MiB embedded flash, the RX600 series offers up to three CAN channels, supporting standard (11-bit CAN-ID) and extended (29-bit CAN-ID) frames. Each CAN module includes 32 mailboxes, of which eight can also be configured as FIFO mailboxes. An acceptance filter mask provides up to eight different masks to be individually set up for each of four mailboxes, which may be enabled and disabled separately. In addition, a 16-bit counter offers a time stamp function. The CAN modules may interact with the RX CPU by using such interrupts as reception complete, transmission complete, receive FIFO, transmit FIFO, and error interrupts. The MCUs have a maximum operating frequency of 100 MHz. In combination with the enhanced RX CPU core architecture, it provides an overall processing performance of 165 DMIPS executing code from the embedded zero-wait state flash. The MCUs also incorporate an on-chip 32-bit multiplier, single-precision floating-point unit (FPU) and a 32-bit enhanced barrel shifter for improved operation processing performance.

The on-chip peripheral functions include timers, four DMA controller channels, Ethernet MAC and up to two USB units. Up to 13 scalable SCIs (UART, SIO and I2C), several A/D and D/A converters and a CRC calculation circuit are also available. The chips with improved EMI/EMS performance comes in 48-pin to 176-pin packages with on-chip flash memory from 64 KiB to 2 MiB and RAM memory from 8 KiB to 128 KiB. The RX600 products are covered by one-tool chain concept.

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CAN API covers this kind of dealing with the CAN peripherals by doing required settings of related CAN registers.

Following function-call blocks are offered by the CAN API:

- Initialization, port and peripheral control
- Send
- Receive
- Error check

The functions for initializing the CAN peripherals e.g. the function ‘R_CAN_Create’ is used to create a CAN connection and will call the other ‘Init’ functions by default. The ‘Send’ functions are used for set up of a mailbox to transmit and to check that it was sent successfully. The ‘Receive’ functions are used to set up a mailbox to receive and to retrieve a message from it. The ‘Error check’ function shows in which CAN state a node is (error active, error passive, or bus-off). This should be used by the application to send messages to the user and restart the application if the node returns from a bus-off state.

Sending first frame

To send first data, the dataframe structure in the memory consisting of CAN-ID, DLC and the actual data should be prepared. Then such a data object should be allocated by defining a structure. Here (as an example) it would be: “my_tx_frame”

```
struct can_std_data_s
{
    uint16  id;
    uint8   dlc;
    uint8   data[8];
};
struct can_std_frame_t
my_tx_frame;
```

Next, an element of this structure is defined:

```
my_tx_frame.id = 0x700;
my_tx_frame.dlc = 2;
my_tx_frame.data[0] =
0x11;
my_tx_frame.data[1] =
0x22;
```

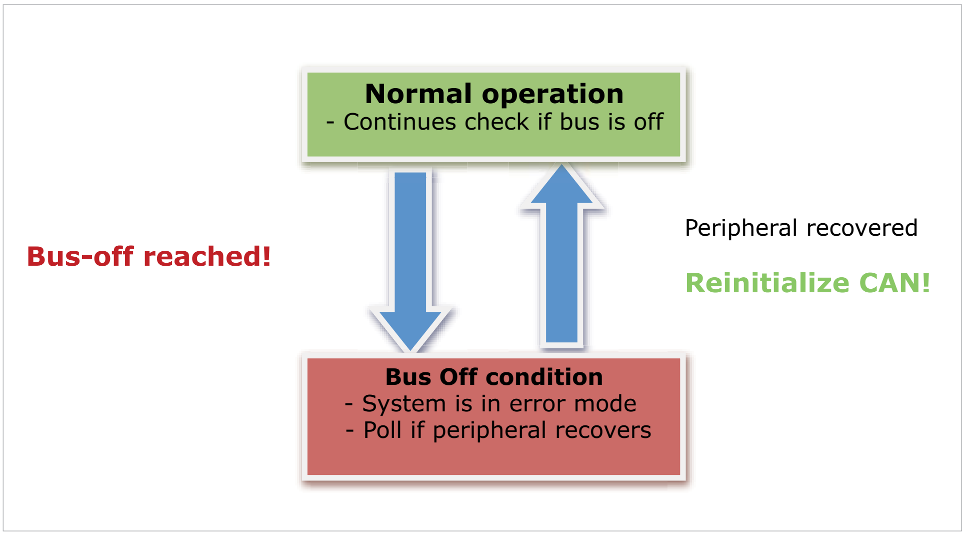

Figure 3: Bus-off handling

Then, the frame using the API function call is sent: `‘R_CAN_TxSet(0, mbox_nr, &my_tx_frame, DATA_FRAME);’`. It is not needed to bother with what the function does in detail. For a reference, the API function will:

- Wait for previous frame to finish transmit
- Clear message control register
- Disable interrupts for mailbox
- Set the CAN-ID
- Set the DLC
- Set transmit data
- Transmit a data frame

Receiving first frame

The API function for setting a slot to receive messages would be `‘R_CAN_RxSet(ch_nr, mbox_nr, stid, frame_type);’`. In this case the API will (unless ‘USE_CAN_POLL’ is defined):

- Wait for any previous transmission/reception to complete
- Disable interrupts for mailbox
- Clear mailbox control register
- Set standard CAN-ID for selected mailbox
- Set data frame/remote frame
- Set receive interrupt enabled

Polling versus Interrupts

There is a choice of polling mailboxes for received (and perhaps sent) messages or using the CAN interrupts. Polling may run in background and will not compete with any other interrupts. It is recommended to use this mode, if the interested data is not required at a certain point in time. In case of a certain timing requirement, processing of messages in order or urgent request of data progressing (e.g. emergency message) an interrupt handling would be the better choice.

When polling is used, ‘USE_CAN_POLL’ is defined in the CAN configuration header (config_r_can_rapi.h), the check transmit function should be called to confirm a transmission. If CAN interrupts are used instead (‘USE_CAN_POLL’ is not defined) the ‘CAN Transmit ISR’ is triggered by the peripheral and a mailbox may then be polled by the ISR for a successful transmission. Afterwards the application has to be

CANopen for RX600

The availability of a CANopen source code library for the RX600 has been established by Port (Germany). The library including NMT master and NMT slave functionality contains the services as defined in the CiA 301 version 4.2 and the CiA 302 specifications. The library has been coded in ANSI-C and hardware-specific interfaces have been placed in separate driver packages (also available in C source code). This should facilitate adaptation to different systems. The scope of delivery includes one driver package for one CPU and one CAN controller.

A fitting CANopen design tool (CDT) enables development of CANopen devices and applications. It automatically generates an object dictionary and an initialization function in C code, an EDS (electronic data sheet) and the documentation of the project. Furthermore, it should simplify the configuration of the CANopen library and of the CANopen driver packages. The library provider offers support packages for the standard Renesas’ starter kits. The CANopen stack and the CDT are already available.

informed that the message was sent.

To receive data frames using polling the API function 'R_CAN_RxPoll(ch_nr, mbox_nr, frame_p);' has to be called. It returns an OK, if a message is waiting. In this case the message needs to be copied to the RAM, by calling the API function 'R_CAN_RxRead (ch_nr, mbox_nr, frame_p);'. The main application needs to the interaction with the received frame.

To receive data frames using interrupt the following should be applied. When CAN data arrives with the CAN-ID set by the API, the receive ISR triggers. The first item to be done in the ISR, should be to call 'R_CAN_RxPoll (ch_nr, mbox_nr, frame_p);' to check which mailbox caused the interrupt. If there is a new message, the ISR should call 'R_CAN_RxRead (ch_nr, mbox_nr, frame_p);', which will copy the data to the frame structure in RAM indicated by the frame pointer argument. Then, a flag should be set to tell the main application that data has been received.

Bus-off state

To treat a bus-off situation the CAN error interrupt or poll with the 'Check Error' function of the API should be used. It should be done once every cycle in the main routine what state the node is in. If the node has reached bus-off a certain number of times within a certain time period, one may want to send a warning message, light an LED, etc. in an application. If this state is reached, the communication should be stopped and polling continued to see when the peripheral has returned to the normal Error Active state. When the node has recovered, it is important to reinitialize the CAN peripheral and the application to make sure that the slots are in a known state. ◀

Summary

This article provides a basic understanding of sending and receiving CAN frames using the CAN API. Each node on a CAN network may have several buffers or message mailboxes. Each mailbox may be assigned a CAN-ID (identifier) that is either unique or is shared with certain other nodes. All nodes receive the message and perform a filtering operation to determine if the message (and thus its content) is relevant to that particular node. Only the node(s) for which the message is relevant will process it.

Dual HS-CAN transceiver with improved EMC

Company
NXP Semiconductors is one of the market-leading manufacturers of CAN transceiver chips. In the portfolio of the Dutch company, there are transceivers compliant to ISO 11898-2 (CAN high-speed), ISO 11898-3 (CAN fault-tolerant with low-power capability), ISO 11898-5 (CAN high-speed with low-power capability), and CAN single-wire transceivers (SAE J1411). In the pipeline are transceivers compliant to ISO 11898-6 (CAN high-speed with low-power and selective wake-up functionality).

Link
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Related articles
Minimum distance between CAN nodes (in: CAN Newsletter December 2011, page 12)
CANopen micro-controller with on-chip transceiver (in: CAN Newsletter March 2011, page 28)
CAN transceiver isolating signals and power (in: CAN Newsletter March 2011, page 24)
Combined transceiver for CAN and LIN (in: CAN Newsletter September 2010, page 40)
CAN physical layer protection hints (in: CAN Newsletter March 2010, page 34)

The TJA1048 is a dual high-speed CAN transceiver that provides an interface between a CAN protocol controller and the physical network wires. The chip is suitable for bit-rates up to 1 Mbit/s. It belongs to the third generation of high-speed CAN transceivers from NXP Semiconductors, offering significant improvements over first- and second-generation devices such as the TJA1040. It offers improved electro-magnetic compatibility (EMC) and electro-static discharge (ESD) performance.

The chip supports two operating modes individually per transceiver: normal and stand-by. The operating mode can be selected independently for each transceiver via two pins (STBN1 and STBN2).

In normal mode, the transceivers can transmit and receive data via the CANH1/CANL1 and CANH2/CANL2 bus lines. The differential receiver converts the analog data on the bus lines into digital data, which is output on the RXD1/RXD2 pins. The slope of the output signals on the bus lines is controlled and optimized in a way that guarantees the lowest possible EME.

In stand-by mode, the transceiver is not able to transmit or correctly receive data via the bus lines. The transmitter and normal-mode receiver blocks are switched-off to reduce supply current, and only a low-power differential receiver monitors the bus lines for activity.

In stand-by mode, the bus lines are biased to ground to minimize the system supply current. The low-power receiver is supplied by V_{IO}, and is capable of detecting CAN bus activity even if V_{IO} is the only supply voltage available. When the RXD1/RXD2 pins goes LOW to signal a wake-up request, a transition to normal mode will not be triggered until the STBN1/STBN2 pins are forced HIGH. A dedicated wake-up sequence (specified in ISO 11898-5) must be received to wake-up the transceiver from a low-power mode. This filtering is necessary to avoid spurious wake-up events due to a dominant clamped CAN network or dominant phases caused by noise or spikes on the bus.

A valid wake-up pattern consists of: A dominant phase of at least $t_{wake(busdom)}$ followed by a recessive phase of at least $t_{wake(busrec)}$ followed by a dominant phase of at least $t_{wake(busdom)}$. The complete dominant-recessive-dominant pattern must be received within $t_{to(wake)bus}$ to be recognized as a valid wake-up pattern. The RXD1/RXD2 pins will remain recessive until the wake-up event has been triggered.

After a wake-up sequence has been detected, the transceiver will remain in stand-by mode with the bus signals reflected on the RXD1/RXD2 pins. Note that dominant or recessive phases lasting less than $t_{fltr(wake)bus}$ will not be detected by the low-power differential receiver and will not be reflected on the RXD1/RXD2 pins in stand-by mode.

A wake-up event will not be registered if any of the following events occurs

▷

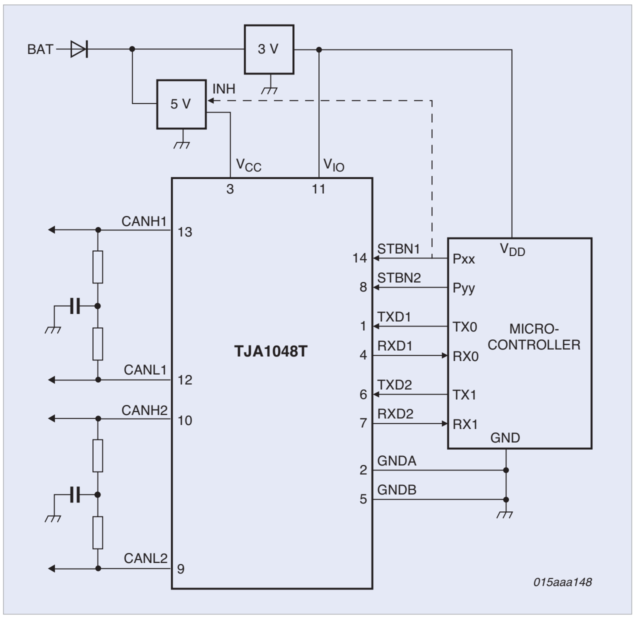
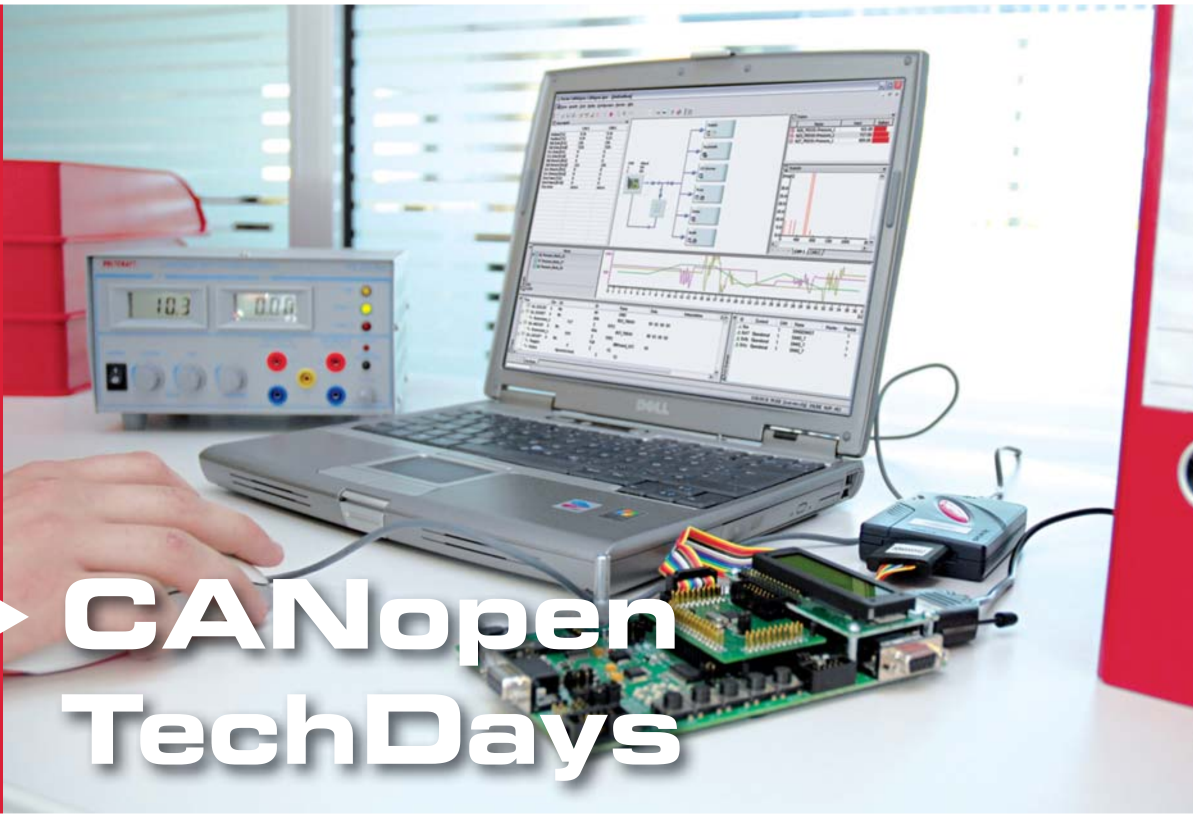


Figure 1: Typical application with 3-V micro-controllers



Vector CANopen TechDays 2012

25.09.2012 in Düsseldorf
26.09.2012 in Berlin
09.10.2012 in Aschheim-Dornach (bei München)
11.10.2012 in Stuttgart

09:00 **Begrüßung**

09:15 **Wettbewerbsvorteile durch Werkzeugeinsatz bei CANopen**

- Einführung in die Basiseigenschaften von CANopen
- Wo helfen Softwarewerkzeuge in diesem Umfeld?
- Einfluss der Basiseigenschaften auf die Testbarkeit
- Was kann man vom CANopen Conformance Test erwarten – und was nicht?
- Was muss vom Anwender darüber hinaus getestet werden?
  - Weitgehende Protokollkonformität
  - Timing
  - Applikatives Verhalten

10:00 **Kaffeepause**

10:30 **Live Demonstration 1: Werkzeugeinsatz im CANopen-Entwicklungsumfeld**

- Wie bekomme ich die EDS-Datei für mein CANopen-Gerät?
  - Aktuelle Marktsituation, Probleme und Lösungsvorschläge
  - Einführung in den EDS-Editor CANeds
- Erste „CANopen Gehversuche“
  - Einführung in die CANopen-Toolumgebung
  - Tracing, Logging, Stimulation: Was ist notwendig und sinnvoll?
  - Woher bekomme ich eine CANopen-Datenbasis?

11:15 **Live Demonstration 2: Teststrategien für CANopen**

- Unterscheidung Gerätetest/Applikationstest
- Wie prüfe ich die CANopen-Konformität?
  - CiA Conformance Test vs. CANoe.CANopen
  - Wie baue ich eine Testumgebung auf?
  - Automatische Testerstellung in wenigen Minuten
- Wie erstelle ich einen Applikationstest?
  - Erstellung eines Testszenarios basierend auf einer generierten Testumgebung

12:00 **Kaffeepause**

12:15 **Flexibles Testen mit dem VT System**

- Einführung in das Vector VT System (I/O-Schnittstellenmodule für den Gerätetest)
- Einfacher Aufbau einer Testumgebung
- Komfortables Erstellen von Testsequenzen mit dem Test Automation Editor

13:00 **Diskussion und Fragen**

13:15 **Mittagessen**

14:00 **CANopen-Konformitätsprüfung mit realer Hardware** (optional, je nach Bedarf)
Danach offenes Veranstaltungsende. Bei einem Kaffee beantworten unsere Experten noch Ihre individuellen Fragen oder testen Ihr mitgebrachtes CANopen-Gerät.

▶ **Weitere Informationen und Anmeldung:**
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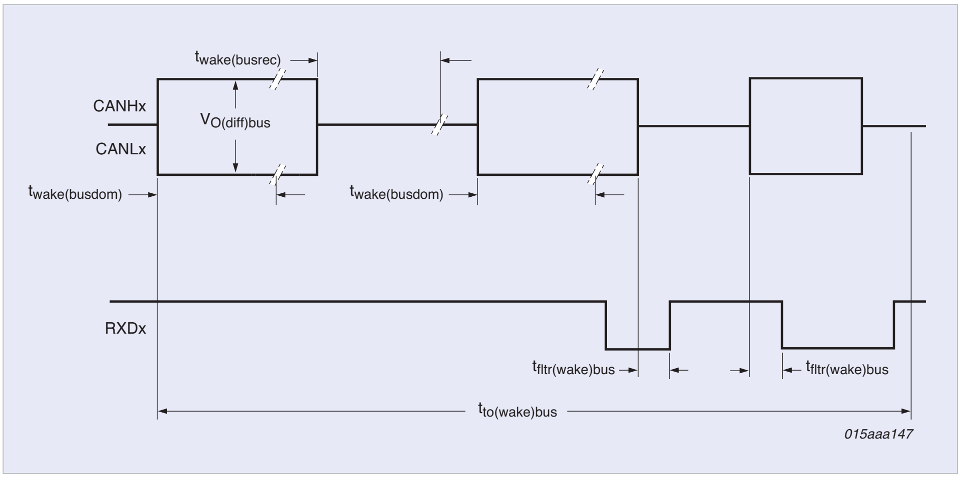

Figure 2: Wake-up time diagram

while a wake-up sequence is being transmitted:

- The transceiver switches to normal mode

The complete wake-up pattern was not received within $t_{to(wake)bus}$

- A V_{IO} under-voltage is detected

If any of these events occurs while a wake-up sequence is being received, the internal wake-up logic will be reset and the complete wake-up sequence will have to be re-transmitted to trigger a wake-up event.

Fail-safe features

A 'TXD dominant time-out' timer is started when the TXD1/TXD2 pins are set LOW. If the LOW state on these pins persists for longer than $t_{to(dom)TXD}$, the transmitter is disabled, releasing the bus lines to recessive state. This function prevents a hardware and/or software application failure from driving the bus lines to a permanent dominant state (blocking all network communications). The TXD dominant time-out timer is reset, when the TXD1/TXD2 pins are set HIGH. The TXD dominant time-out time also defines the minimum possible bit-rate of 40 kbit/s. The chip has two TXD dominant time-out timers that operate independently of each other.

The internal biasing is achieved by means of pull-up and pull-down resistors. The TXD1 and TXD2 pins have internal pull-ups to V_{IO}. The STBN1 and STBN2 pins have internal pull-downs to GND_A and GND_B. This ensures a safe, defined state if any of these pins is left floating. The GND_A and GND_B pins must be connected together in the application. The pull-up/pull-down currents flow in these pins in all states. The TXD1 and TXD2 pins should be held HIGH in stand-by mode to minimize stand-by currents; the STBN1 and STBN2 pins should be held LOW.

Should the supply voltage drop below the V_{CC} under-voltage detection level, both transceivers will switch to stand-by mode. The logic state of STBN1 and STBN2 pins will be ignored until V_{CC} has recovered. Should V_{IO} drop below the V_{IO} under-voltage detection level, the transceivers will switch off and disengage from the bus (zero load) until V_{IO} has recovered.

The output drivers are protected against over-temperature conditions. If the virtual junction temperature exceeds the shutdown junction temperature, both output drivers will be disabled. When the virtual junction temperature drops below $T_{j(sd)}$ again, the output drivers will recover independently once TXD1/TXD2 has been reset to HIGH. Including the TXD1/TXD2 condition prevents output driver oscillation due to small variations in temperature.

The V_{IO} pin should be connected to the micro-controller supply voltage. This will adjust the signal levels of the TXD1, TXD2, RXD1, RXD2, STBN1 and STBN2 pins to the I/O levels of the micro-controller. The V_{IO} pin also provides the internal supply voltage for the transceiver's low-power differential receiver. For applications running in low-power mode, this allows the bus lines to be monitored for activity even if there is no supply voltage on the V_{CC}.

TJA1048 features

- *Two transceivers based on TJA1042 combined monolithically in a single package*
- *ISO 11898-2 and ISO 11898-5 compliant*
- *Suitable for 12-V and 24-V systems*
- *Low electro-magnetic emission (EME) and high electromagnetic immunity (EMI)*
- *V_{IO} input allows direct interfacing with 3-V to 5-V micro-controllers*
- *Available in SO14 and HVSON14 packages)*
- *Low-current stand-by mode with host and bus wake-up capability*
- *Transceiver disengages from the bus when not powered up (zero load)*
- *Wake-up receiver powered by V_{IO}; allows shut down of V_{cc}*
- *Bus pins protected against transients in automotive environments*
- *Transmit data (TXD) dominant time-out function*
- *Under-voltage detection on pins V_{cc} and V_{IO}*
- *Thermally protected*

Reference

TJA1048 product data sheet: Dual high-speed CAN transceiver with stand-by mode.

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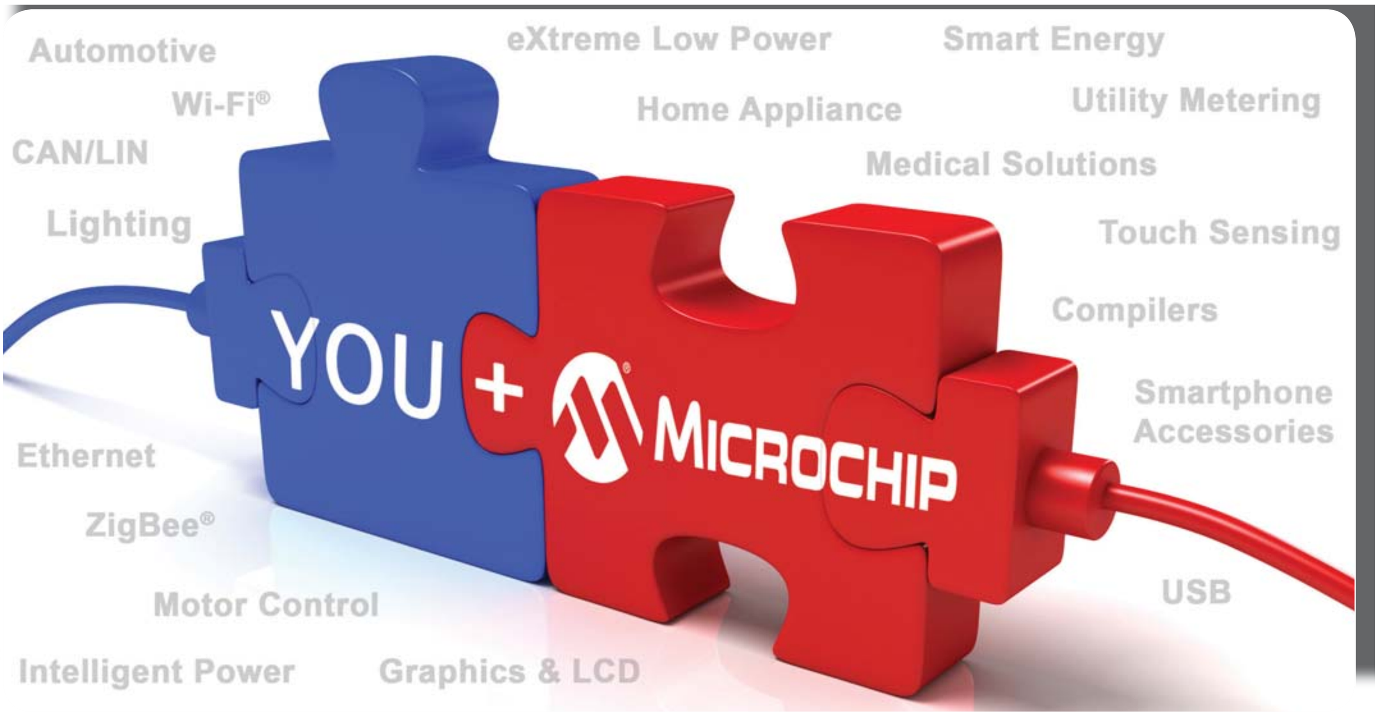

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