September 2017

CAN Newsletter

Hardware + Software + Tools + Engineering

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Sensors

PCAN-miniPCIe FD

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- Programming interfaces for standardized protocols from the automotive sector like:
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  - **PCAN-XCP API** for communication with ECUs according to the Universal Measurement and Calibration Protocol (CAN FD support since version 2)
  - **PCAN-ISO-TP API** for the transfer of data packages according to ISO-TP (ISO 15765-2)
  - **PCAN-UDS API** for the communication with ECUs according to UDS (ISO 14229-1)
  - **PCAN-OBD-2 API** for vehicle diagnostics according to OBD-2 (ISO 15765-4)

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PEAK-System Technik GmbH

Otto-Roehm-Str. 69, 64293 Darmstadt, Germany
Phone: +49 6151 8173-20 - Fax: +49 6151 8173-29
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Sensors

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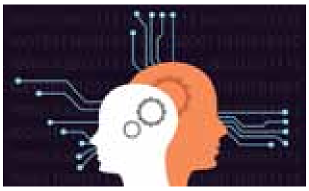

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publications@can-cia.org
www.can-cia.org

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

CEO
Holger Zeltwanger
Reiner Zitzmann

AG Nürnberg 24338

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Editors
pr@can-cia.org

Cindy Weissmueller
Holger Zeltwanger
(responsible according to the press law)

Layout
Nickel Plankermann

Media consultants
Gisela Scheib
(responsible according to the press law)
Gertraud Weber

Distribution manager
Holger Zeltwanger

CiA booth at Interlift 2017 in Augsburg (Germany)

As usual, CiA exhibits its CANopen Lift demonstrator at the bi-annually Interlift tradeshow. CANopen Lift, standardized in the CiA 417 application profile specification series, is the only open CAN-based network standard supported by different suppliers. The demonstrator comprises several independent lift/elevator applications.

The Interlift takes place from October 17 to 20 in Augsburg (Germany). Two years ago, more than 20 000 people from 100 countries visited the exhibition. This year, the fair covers 44 000 m², around 2000 m² more than 2015.

CAN-connectable sensors look optimistic into the future

The trend to more complex devices is ongoing. This is also true for sensors. Thus they require more sophisticated communication interfaces.

Hot and cold: Smart devices support sensor fusion not just in road vehicles (Photo: Fotolia)

Any electronic control system comprises three parts: input, processing, and output units. Even very complex control systems with one or several embedded networks consist of these three unit categories. Inputs include measuring devices also known as sensors. These sensors are going to become more complex. Even a simple inclinometer is not that simple. It needs to compensate not just temperature changes but also it should consider accelerations and decelerations in some applications. This is sensor fusion. Of course, the sensor fusion applications for automated and autonomous driving are more complex combing cameras, radars, and lidars.

CAN technology, in particular the CAN FD protocol featuring a higher bandwidth and payloads up to 64 byte, is a good candidate for those more complex sensor systems. Besides, the carmakers and manufacturers of commercial vehicles including machines on wheels are driving sensor fusion. Another application field is service robots and collaborating mobile robots, which requires similar complex sensor systems. In battery-powered systems they need to consume as less power as possible. This means they should be light weighted.

The transmission of sensor data is essential for all control applications. End-users should not underestimate the robustness and reliability, which CAN communication provides. Additionally, the CAN hardware is available for very reasonable costs. The higher-layer protocols are well standardized (e.g. CANopen and J1939) and field-proven. CANopen specifies several sensor types by means of device profiles.

Sensors are the base of what is called the Internet-of-Things (IoT). They provide the base for big data processing. CiA is developing standardized solutions to connect CANopen sensors to the clouds: The CiA 309-5 gateway specification is one, another one is the OPC UA compendium specification, specifying the mapping of CANopen networks. Recently, CiA started discussion on this topic with the nonprofit SGET association and CiA is also involved in VDA's IoT approach for body electronics in commercial vehicles. ◀

Author

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

Selection criteria for linear and rotary encoders

Encoders are used in very different applications. The used measuring methods (optical or magnetic length and angular) meet more or less the application requirements.

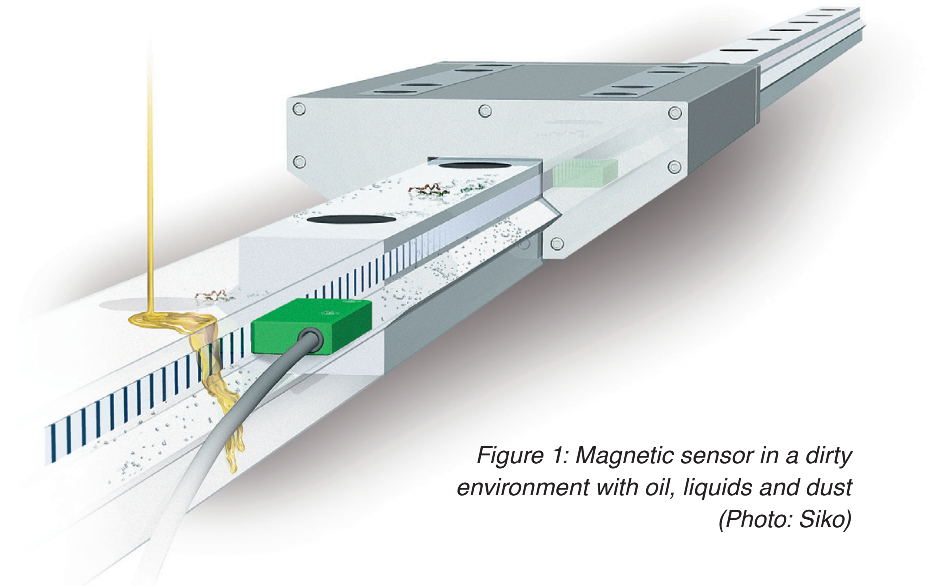


Figure 1: Magnetic sensor in a dirty environment with oil, liquids and dust (Photo: Siko)

The requirements of length and angular measurement procedures are highly varied, and consequently a broad product spectrum has emerged in recent years. By clarifying certain key data at an early stage, however, the selection of an appropriate system can be made considerably simpler.

Precise length measurement is a fundamental requirement in industrial production. Yet the specifications of the measurement systems are as varied as the fields of application in which the sensors are used. While it may be necessary to measure distances of up to a hundred meters in cold conditions in a warehouse, the biggest challenge faced in mechanical engineering is sufficient precision. Furthermore, contamination caused by ambient media often hampers the measurement process: In a woodworking environment, for example, sensors have to function reliably in spite of high exposure to dust. When used in wet-processing with CNC-controlled milling machines, sensors are constantly exposed to lubricoolants.

The capacity of the measurement system to function even under harsh environmental conditions, together with its precision and the economic viability of the system, is one of the main arguments for selecting the appropriate measurement technology. Owing to this diversity of requirements, in recent years a wide product spectrum has been developed. In technological terms, magnetic sensors border on the level of precision of optical systems. There are nevertheless certain applications that demand such high precision that only optical systems can be considered. Compared to magnetic systems, however, these are more sensitive to external influences such as dust or fluids. Encapsulating the sensors can help protect them, say, from harmful emulsions in a CNC milling environment. This is however a costly undertaking.

When selecting an appropriate length measurement process the following factors should be considered first: the higher the required precision, the more important it will be to use an optical measurement process. As regards the operational environment, however, the following basic principle applies: The greater the contamination of the operational environment through dust and liquids are, the more obvious are the benefits of magnetic solutions. Uwe Frey from Siko stated: "The most decisive factor is the level of precision required. If the customer wishes to measure an area with a precision tolerance of ± 5 µm, then there is little doubt that an optical system should be used. As for magnetic sensors, these can offer precision of up to ± 10 µm." However, he also pointed out how much has changed in the field of magnetic systems in the past." Even just a few years ago, values less than ± 25 µm were unheard in magnetic systems. For high-precision applications there was no choice but to use optical processes." The smaller pole pitch of the measuring strips that can be obtained using modern production techniques has mean-while enabled the accuracy of magnetic measurement processes to be greatly improved.

Since 1963, Siko has established itself as a provider of measurement technology for various tasks such as length, angle, and rotational speed measurement as well as for the measurement of inclination and speed.

The Magline range of magnetic length and angle measurement products has been steadily improved in recent years. The highest level of repeatability is obtained in this product line (to the level of 1 µm). The resolution is 2 µm. Some of these products feature CANopen connectivity (e.g. CiA 301 and CiA 406). The bit rate is adjustable

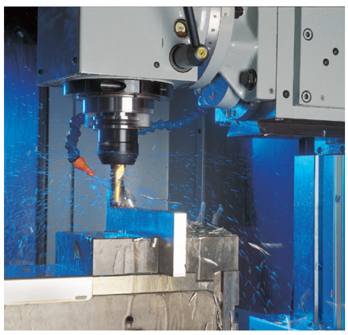


Figure 2: Application in an hard environment – swarf and lubricants at a CNC -machine (Photo: Siko)

from 50 kbit/s to 1 Mbit/s. The magnetic tapes are produced in-house. The manufacturer has developed a special process for coding the measurement tapes. Depending whether the measurement process required is incremental or absolute, one or more magnetic code tracks is attached. Recent product developments have also proved remarkable in terms of repeatability and the axis speeds that can be achieved.

If more precision is required, optical sensors are the choice. They can reliably record measuring steps even at high traverse speeds (3 m/s and 1,5 m/s respectively). The products can be used as length measurement systems for up to 30 m as well as an angle sensor for measurements below 360 degrees.

The optical sensors evaluate information on an optical measuring tape using a laser-based technology. The positional values are forwarded to the downstream electronics as digital counter pulses (A, B, R). The technique makes use of the Talbot effect: light is distributed at defined spacings in the pattern of a grating. A grating structure is also created behind the sensor head. This grating is now irradiated with monochrome waves, so a wider light distribution is obtained behind it. This technique allows a comparatively large distance between the sensor and the optical rule. With this technology the sensor head can be made very small. For applications in which dimension is a critical factor, this method is ideal.

The precision of optical sensors is very high and lies in the range of about ± 5 μm. Compared to the magnetic system with its precision of ±10 μm, this represents a doubling in precision. On top of this, the resolution of 0,05 μm is greater by a factor of four than the 0,2 μm currently offered by magnetic systems.

Another advantage of the optical system is its insensitivity to magnetic disturbances. When linear motors are used, for example, electromagnetic interference can occur in the form of stray magnetic fields that can falsify the position values of a magnetic sensor. Yet linear motors are one of the main areas of application for magnetic sensors at Siko – especially when the motors are used under harsh ambient conditions. This is because the stray magnetic effect of the linear motors is only critical if the sensor head and magnetic tape are positioned too close to the motor. If the user maintains a defined safety clearance between the sensor and the motor or fits a shield, interference can be avoided. The farther away the motor is from the sensor, the less it affects the sensors. Accordingly, the real benefit of optical sensors becomes evident in situations, in which space is restricted or very powerful magnetic fields are present. For purely physical reasons, in magnetic systems a hysteresis effect arises in relation to the measured values. No such effect occurs in optical systems since they are not prone to electromagnetic influences.

By contrast to magnetic systems, optical systems are sensitive to environmental factors such as dust, swarf, oil, and grease. In harsh conditions protection is also required ▷

Reference

[1] High productivity with open motor feedback systems. White paper, Siko, Buchenbach, Germany.

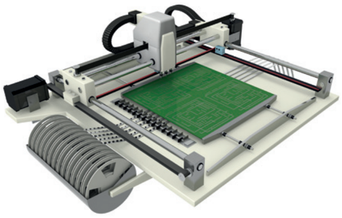


Figure 3: Compact optical sensors are predestinated to record length information at a pick-and place machine (Photo: Siko)

for the measurement system against shock and vibration stresses and dirt. The measurement technology is also affected by temperature fluctuations and high air humidity; any formation of condensation on the code strips can result in measurement errors. To avoid this, elaborate housings can be created for protection against the influences described above. But they are costly.

A further disadvantage of optical measurement technology is the installation and handling by technical personnel. When sensors are mounted, their mechanical tolerances are dependent on the guide to which they are attached. An optical sensor must be adjusted precisely if the mechanical tolerances are to be offset. The sensors must always be moved exactly equally over the rule in order to obtain accurate values consistently. Dust and dirt must not be allowed to affect the sensor even during installation; measures must be taken to prevent this occurring.

Optical measurement systems with their high precision and repeatability are frequently required in, for example, pick-and-place automation, production and inspection machinery in the semiconductor industry, positioning and measurement equipment in medical systems and analysis technology. Further areas of application include ultra-precision machines and high-precision equipment, measuring microscopes and other high-precision measurement instruments. Vacuum-based applications can also be realized using measurement systems.

Magnetic tape length sensors

While optical systems are not longer than 30 m, magnetic systems are available for up to 100 m. As a rule, applications of this kind, such as warehouse logistics, do not call for extreme levels of precision. Far more important in such situations are mechanical resilience and insensitivity to environmental influences. Magnetic sensors are resistant to dirt, oil, and moisture and relatively robust when exposed to shock and vibration. As well as linear measurement, magnetic measurement systems can be used for rotational measurements of angles greater than 360 degrees.

As mentioned above, magnetic systems generally have lower levels of absolute precision, resolution and repeatability. A magnetic field such as is present in a magnetic sensor can be detrimentally influenced by external ferromagnetic interference. This sensitivity to stray magnetic fields can reduce measurement accuracy. It may be noted that the disadvantages of magnetic measurement technology concerning measurement accuracy and ferromagnetic interference explain the advantages of optical measurement principles.

Magnetic measurement technology is robust and is used for contactless path and angular position measurement. The fields of application of magnetic sensors are many, covering all areas of mechanical engineering and industrial automation. They are used, for example, in linear and rotational drive systems (direct drive systems and motor feedback), in production machinery for furniture and parquet flooring and even in high-tech medical applications such as computer tomography. They are also suitable for extreme applications such as stone processing and glass machining. Magnetic sensors have also proven themselves particularly effective for the mirror tracking systems of solar power collectors and in stage technology, in forklift trucks and in waste and scrap compaction equipment.

In linear drive applications, both magnetic and optical sensors are commonly used. The deciding factor is the sensitivity of the measurement system to stray magnetic fields, since linear motors can create electromagnetic radiation in their vicinity that has a negative effect on the magnetic sensor. Where the motors are used in harsh conditions, however, magnetic sensors have become the established choice despite their sensitivity to magnetic interference, provided that a defined safety distance is maintained between sensor and motor.

Path measurements of circular movements have specific challenges. Despite the fact that turning and swiveling are standard operations in mechanical engineering, they nevertheless pose challenges to the designers of measurement systems that should not be underestimated. Siko offers magnetically coded measuring tapes in the form of flexible magnetic rings with no flange or glued with a metallic ring (flange). By attaching the tape to the ring, joints would unavoidably occur that would cause measurement errors. To prevent this, Siko has established its own ring production facility in which the tape is first attached and then coded. This assures a system precision of up to ±0,05 degrees. In addition to a portfolio of rings in different sizes, the German company also offers custom modifications. From a certain ▷

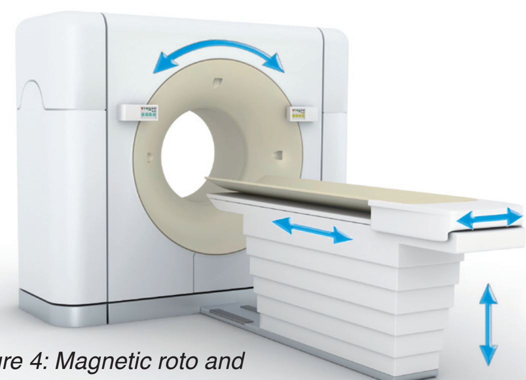


Figure 4: Magnetic roto and length measurement at a CT-Scanner (Photo: Siko)

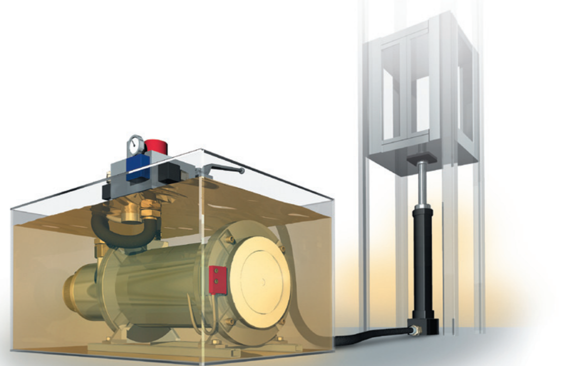


Figure 5: MagLine Roto with a resolution of max. 0,001° in harsh environment (Photo: Siko)

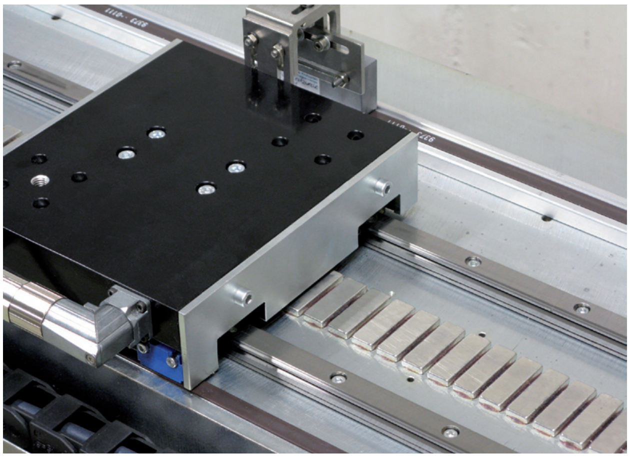


Figure 6: Magnetic sensor supply the required position feedback at a linear motor (Photo: Siko)

flange diameter upwards, the manufacturer tapes can be fitted by the customer to allow angle measurements below 360 degrees.

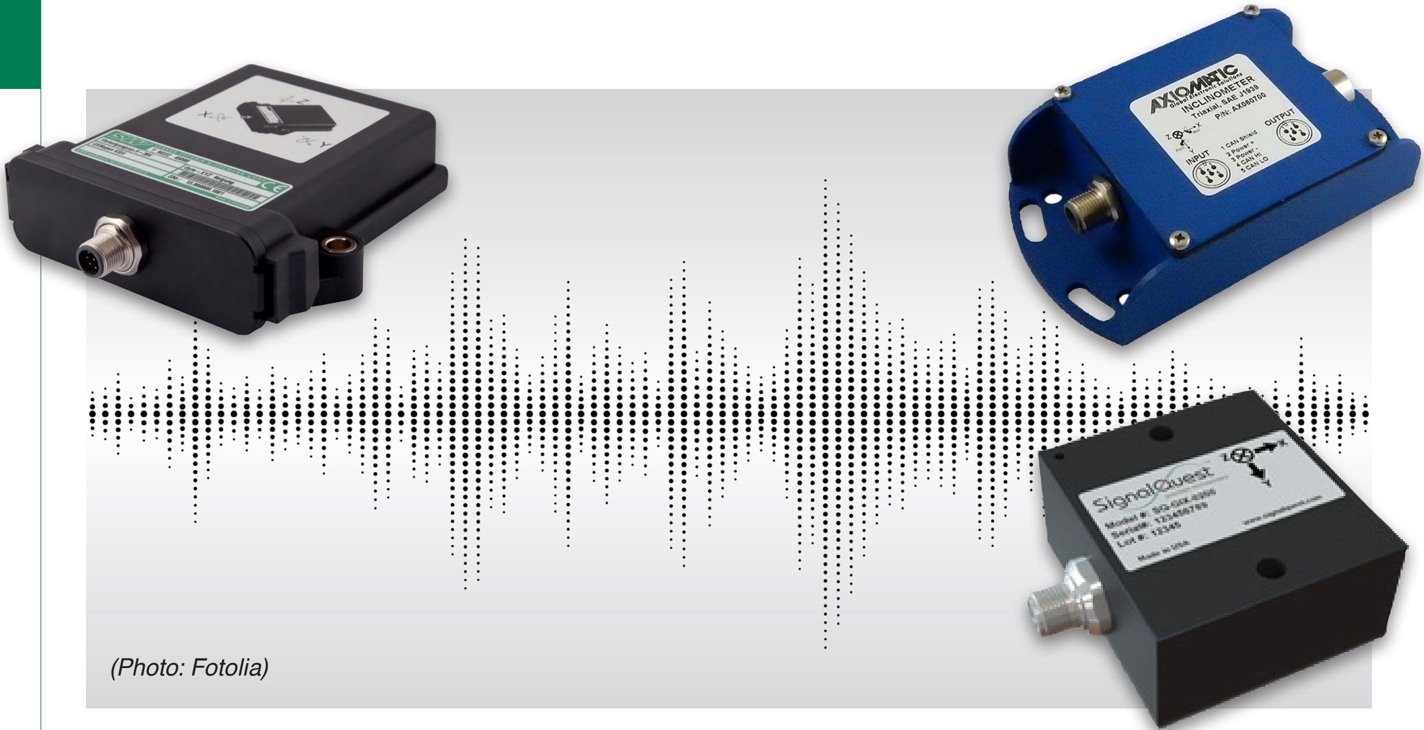
For magnetic sensors Siko offers ready finished measurement rings that have such a high quality of manufacture that they can be used for measurements greater than 360 degrees. As for optical sensors, the providers often do not offer rings but rather measurement tapes that are affixed to the flange. From a diameter of 50 mm upwards, angle functions below 360 degrees can be measured. The handling of the tapes in rolled form is significantly more demanding in the case of optical systems and must be performed by trained personnel with suitable qualifications. As a consequence, while swiveling axes can be measured using optical sensors in an open construction design, continuous rotational movements cannot. Thus optical sensors can be used successfully with this technique to capture the cutting angle of a saw in mitering operations, while the rotations of the shaft of an electric motor are much more easily recorded using a magnetic system (such as a bearing-free system). ◀

Author

Kerstin Graw
Siko
kerstin.graw@siko.de
www.siko.de

More than an inclinometer

Because simple (static) inclinometers measure correctly only in standstill, they need to integrate other sensor elements and require some software to compensate physical effects caused when they are moved.



(Photo: Fotolia)

Sensor fusion is a trend not limited to the automotive industry. Also other applications require combining different sensor elements, to process the measured values, and to provide a calculated measurement. Tilt sensors in mobile machines need to measure the inclination during movements. Already a couple of years ago, first providers compensated tipping and other dynamics. Sensortechnik Wiedemann (STW) located in Germany, for example, introduced in 2011 the NGS1 device combining tilt, temperature, and gyroscope sensors (see CAN Newsletter 3-2011, page 60/61). In the meantime, many other suppliers have introduced similar products measuring inclinations correctly even under very harsh conditions.

Such dynamic inclinometers are based on MEMS (micro electro-mechanical system) technologies and deeply embedded micro-controllers processing the sensor values with highly manufacturer-specific algorithms. The compensations lead to improved accuracy without changes in the interface. Some devices also compensate high and low temperatures. Therefore, they implement a temperature sensor, too.

The implemented compensation algorithms are manufacturer-specific and depend highly on the implement MEMS solutions. The AMU-GEO inclinometer jointly developed by C.O.B.O (Italy) and TKE (Finland) compensates vibration and shock as well as centrifugal acceleration. This means the device measures single axis in 360 degrees. Especially, in load monitoring and collision detection functions of booms, the centrifugal acceleration is one of the main root causing measurement errors. They need to be compensated. This is why additional sensor elements are integrated in inclinometer. This includes accelerometers and gyroscopes.

Accelerometer and gyroscope

The accelerometer measures acceleration. They are well known in the aircraft industry. A 3-axis component provides the orientation of the installation platform relative to the surface of the earth. When the platform is moving, things become more complicated. In free-fall, the platform shows zero acceleration. If it is accelerating in a particular direction, that acceleration is simply be added to whatever acceleration is being provided by gravity, and you will not be able to distinguish. A 3-axis accelerometer in an aircraft in a properly coordinated turn with a 60-degree angle of bank, for instance, will show 2 g "vertical" gravity in the aircraft, despite the fact that the aircraft is tilted 60 degrees relative to the horizon. This means, accelerometers are not sufficient to keep an aircraft in a particular orientation.

A gyro sensor measures rate of rotation around a particular axis. If it is used to measure the rate of rotation around the aircraft roll axis, it measures a non-zero value as long as the aircraft is rolling, but indicates zero if the roll stops. This means, a roll gyroscope in an aircraft in a coordinated turn with a 60-degree bank measures a rate ▷

Figure 1: Several inclinometers integrate accelerometers and gyroscopes, in order to compensate movements including vibrations and shocks (Photo: Posital)

of zero, same as an aircraft flies straight and level. You can approximate the current roll angle by integrating the roll rate over time, but you cannot do it without some error creeping in. Just to make life more interesting, the gyroscope drifts with time, so additional error will accumulate over a period of minutes or even seconds, and eventually, you have an inaccurate idea of your current roll angle relative to the horizon. So, gyro-sensors alone cannot be used to keep an aircraft in a particular orientation. So, in an aircraft, you need both, in moving tilt sensor to measure the inclination and to evaluate it correctly.

If there are only linear accelerations and mechanical shocks to be compensated, it is sufficient to add a gyroscope. In applications such as ship platforms, working platforms, or oilrigs, inclinometers combined with gyroscope can be used. FSG (Germany) offers, for example, the PE-MEMS GS70 series with integrated gyroscope. The IP68-rated device compensates mechanical shocks. The redundant device gauges x-axis and y-axis angles in a measuring range of ±60 degree. It achieves accuracies between ±0,05 degree and ±0,3 degree for angle ranges between ±60 degree. The sensors tolerate temperatures ▷

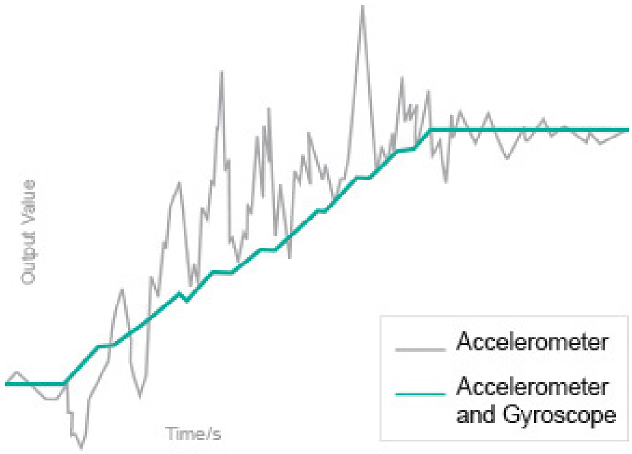


Figure 2: Tilt measurements on a moving excavator with and without compensation (Photo: Posital)

between -40 °C and +70 °C and meet technical safety requirements according to the IEC 61508 (SIL 2) and EN 13849 (PLd) standards. The sensor device provides a CAN interface and runs the CANopen or CANopen safety protocol. Sensors with functional safety features satisfy an increasing demand on mobile machinery compliant to the European machine directive.

CANopen and J1939

Inclinometers for dynamic measurements are available with CANopen and J1939 support. Most of the offered CANopen inclinometers comply with the CiA 410 profile. It was first introduced in the year of 2000. In those days, there was no compensation implemented. There is no big need for further expansions in the profile. The last bigger change was the introduction of CANopen Safety parameters.

Nevertheless, in some applications, it would be nice to have the raw values from the integrated accelerometer and gyro-sensors. In particular, if individual sensor elements are used, this could be an option. Also a third axis is on the wish list. Some users like to switch-on and switch-off compensation. This is also a missing feature in the CiA 410 profile. From a system designers' point-of-view, parameters defining the measurement accuracy would be great, as defined in CiA 406, the CANopen profile for rotary and linear encoders. This would enable the use of an EDS as a master datasheet. Further detail is, that certain compensations may have specific flags in the upper word of device type in order to help run-time consistency monitoring of the devices. Based on experience of TKE and C.O.B.O., at least two flags are needed: for vibrations/shocks and for centrifugal acceleration.

Another supplier of CiA 410-compliant dynamic inclinometers is Posital. Its Tiltix inclinometer uses software algorithms to compensate dynamically accelerations. The IP69K-rated product is based on MEMS accelerometers that rely on monitoring the effect of gravity on a tiny mass suspended in an elastic support structure. To compensate measurement errors due to rapid motions, electromechanical gyroscopes have been implemented, too. The inclinometer has a measurement range of ±180° in two axes. Other features include 0,01-degree resolution, 0,3-degree accuracy (0,5 degree during movements), -40 °C to +85 °C temperature, and up to 100-g shock resistance. The device can be mounted horizontally or vertically.

In order to have all the internal additional data available, STW implemented the CiA 404 multi-channel measurement device profile in its NGS2 inclinometer featuring gyroscope functionality. Introduced end of last, beginning of this year, the three-axis device achieves a resolution of 0,25 degree. Unfortunately, the channel assignment to the measured data is not standardized. This decreases the interoperability with other products. Nevertheless, it is in some applications a benefit to have some sensor internal data available for evaluation purposes.

The inclinometer with J1939 connectivity uses normally proprietary PGNs (parameter group number). Axiomatic offers its IP67-rated 3-axis inclinometer with integrated gyroscope and accelerometer with a CAN interface and a J1939 protocol stack. It transmits angular and angular rate data. The default configuration can be changed using the company's PC-based Electronic Assistant software. ▷

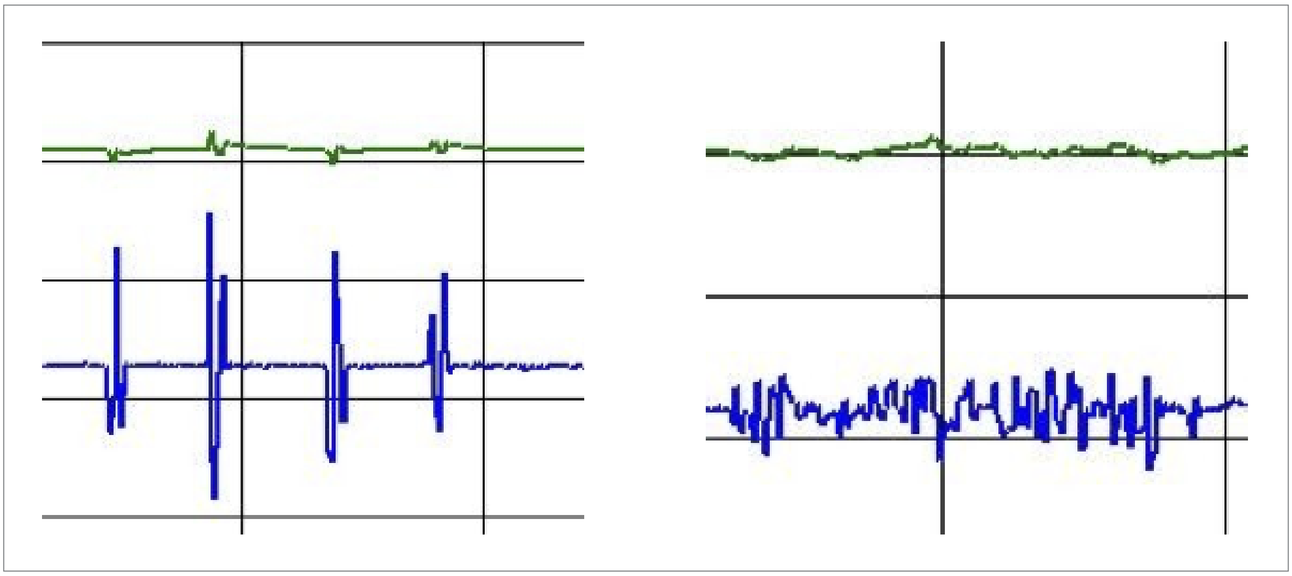


Figure 3: Chock (left) and (vibration) have huge impact on tilt measurements; the green line shows how well the compensation in the AMU-GEO works (Photo: TKE)

The sensor measures pitch and roll inclination angles in a ±180-degree orientation range. The integrated gyroscope compensates the pitch angle to minimize the influence of dynamic linear accelerations. The unit also outputs gravity angle and accelerations in three orthogonal directions as well as an angular rate of rotation around the pitch angle.

Figure 4: The Gravitygyro sensor can queue up to 12 CAN messages and is like others a drop-in upgrade for legacy (static) inclinometers (Photo: Signalquest)

The angles are measured by a set of MEMS sensors, which senses acceleration caused by the gravity force in three orthogonal directions. The output signals from the MEMS sensors are normalized and processed by the embedded Cortex-M3 micro-controller.

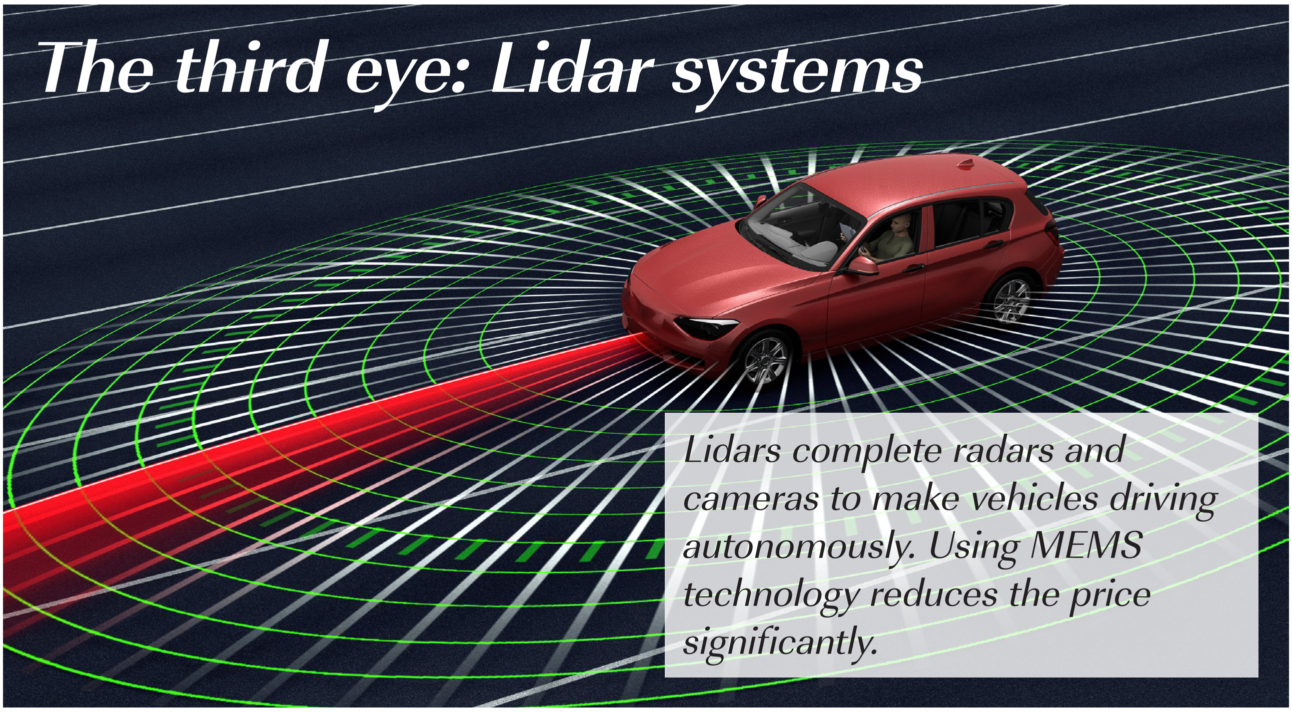
Another supplier of J1939-connectable dynamic inclinometers is Prova Systems. Its Vehicle Inertia Monitor (VIM) is a tilt sensor with a dual-mode vibration analyzer for heavy-duty vehicle prognostics and performance monitoring. The vibration mode helps maintenance engineers recording equipment performance over time to characterize normal operating metrics. It captures and highlights changes in vibration through use of high-resolution sub-Hz analysis via multi-rate signal processing. The inclinometer incorporates the vehicle kinematic model and Kalman filtering for real-time attitude estimates. Gyroscope and accelerometer data is fused via Kalman filtering. The sensor compensates for vehicle frame longitudinal and lateral accelerations as well as gyroscope precession compensation supports vehicle maneuvers on inclined surfaces.

Signalquest is another inclinometer provider supporting CANopen and J1939 connectivity. Its SQ-GIX-0200 Gravitygyro sensor is designed to replace static inclinometers. It handles like the above-mentioned competing products by itself all the complexity of multi-axis inertial calibrations, quaternion angles, Kalman filters, and dynamic adaptive sensor fusion. This is completely transparent to the user. ◀

Author

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

The third eye: Lidar systems



Lidars complete radars and cameras to make vehicles driving autonomously. Using MEMS technology reduces the price significantly.

(Photo: Fotolia)

Lidar (light detection and ranging) measures like radar the distance of an object by means of the time the reflected laser beam needs to come back to the emitting system. This technology was originated in the early 1960s. First applications were measuring clouds and mapping the moon's surface during the Apollo 15 mission. Nowadays, lidars are used to give sight to vehicles. They are so-to-say the third eye completing radars and cameras. They form 3D images by bouncing laser beams in the vehicle's path. They can also function in snow and rain under certain conditions. After the deathly accident a Tesla car has had last year, when the so-called autopilot was on duty, it was speculated that the vehicle's cameras could not identify the white trailer against the bright sky. The carmaker has stated before that Lidar technology does not make sense in automated driving cars. Lidars are able to overcome this camera weakness.

To be serious, in the past lidars were expensive: up to €1000 and more. For high-volume applications, this is not acceptable. Using MEMS (micro electro-mechanical system) technologies this could be decreased dramatically. Continental and Valeo will produce solid-state lidar products by end of this decade. But there are still challenges to meet – especially, the carmakers requirements regarding temperature range, reliability, and robustness. Not to forget, not all lidars are eye-safe. Along with the cost factor, the lidars have to be improved regarding reliability. In the safety-critical aspects of automotive manufacturing, the equipment has to demonstrate the "six nines" – 99,9999-percent reliability.

Lidars could be used for lane tracking as well as obstacle and hazard detection. The lidar data is normally fused with other data coming for example from radars, cameras, GPS systems, odometers, or inertial sensors. The data fusion requires dedicated algorithms running on number crunching processors, e.g. such provided by Nvidia. Dibotics promotes another way: The French company has developed a 6-degree of freedom sensor-agnostic localization technology, relying exclusively on the data originated from a single lidar sensor. Demonstrated at the Concarexpo 2017 in Berlin, this approach does not need artificial intelligence (AI) and deep learning. It just uses state-of-the-art micro-controllers. The real-time results are predictable and comply with functional safety requirements, stated the company.

Most lidars use a time-of-flight (TOF) method. Some sensors use just phase to get position by scanning with a modulated signal that changes in frequency, distance is determined by looking at the frequency and phase. These sensors are more costly.

Other products use triangulation. These sensors can typically provide very accurate distance, however they are often not eye-safe. It is also possible to combine the described methods.

The reflectivity of a surface is important for the maximum range of a lidar. A white surface will typically have a better return than a black surface (black rubber and coal are particularly bad). Another thing that affects reflectivity is the surface type. A smooth surface will typically reflect better than a rough surface.

Also the stop size (has some relevance for rain drops) should not be forgotten. It should be specified for both directions. As the range increases, the distance between each of the points increases. The spot size of each point can be over 1 m in distances of 100 m. If the lidar provides multiple returns, this improves the measurements in rain, snow, fog, or when leaves are falling.

The first lidar generation was based on short-wave infrared (SWIR) diodes, avalanche photodiode or single-photon avalanche diode and used optical systems. It was a race on performance and durability. The need to reduce costs brought solid-state technology into the game: steerable lasers, MEMS-based micro-mirrors, and detector arrays.

In the pipeline: solid-state lidars

The contest has been started already: besides ST-Microelectronics, there are Ibeo (partner of ZF), Innoluce (cooperating with Infineon), Innoviz (partner of Magna), Ledartech ▷

(partner of Valeo), Quanergy (cooperating with Sensata), Trilumina (partner of Denso), Velodyne (cooperating with Ford), and Xenomatix developing solid-state lidars. The Tier1s integrate them into ADAS (advanced driver-assistant system) units featuring sensor data fusion. Xenomatic, for example, provides the Xenolidar solid-state sensor packed into the Xenotrack test-kit operating in all light and weather conditions. The kit comes with the Xenoware software supporting data transfer via CAN and other interfaces. Ibeo's lidar products are also connectable to CAN networks using the CAN gateway by HMS/Ixxat.

Quanergy's 3S solid-state lidar has received the CES 2017 'Best of Innovation' award. It is able to perform real-time 3D mapping and object detection, tracking, and classification of objects in distances up to 200 m. The lidar sensor has been integrated into Koito's headlights. It emits collimated light pulses in a 120-degree arc. Light receivers detect the reflected light pulses. Signal processors calculate the TOF. With the ability to scan in every direction, the unit creates a live 3D-view around the vehicle. The company also offers the S3-Qi lidar with a maximum range exceeding 100 m. This solid-state sensor is suitable for drones, robots, and industrial automation. Quanergy cooperates exclusively with Sensata integrating the lidar sensors with cameras and other components.

Ibeo cooperating with ZF, another German Tier1 supplier, has introduced the Scala fusion system comprising up to five laser scanners. The sensors emit laser beams with a wavelength of 905 nm, which ensures eye-safety. Each sensor requires one Media Converter Box by Valeo. It packs the lidar sensor data into Ethernet frames. The ECU, which performs the data fusion, collects also vehicle speed and yaw rate via its CAN interface. The camera data comes via the USB port. The calculated and commanded vehicle motion data is transmitted via the used in-vehicle network, normally CAN or Flexray.

Microvision uses in its lidar sensors MEMS mirrors. But instead of visible light laser diodes, the company utilizes one or several invisible near infrared (IR) laser diodes. The IR beam is reflected onto the biaxial MEMS scanning mirror that scans the beam in a raster pattern. The lidar unit also contains an IR photo-detector that detects reflections from the scanner IR laser beam. Since speed of light is constant and know the time is known when the specific laser pulse is emitted and when the reflection back receive is received, the unit can calculate the distance to the object. The lidar sensor is able to capture 5,5 million points per second. The MEMS-based laser scanners are scalable and can therefore be used in very different applications. Microvision cooperates with ST Microelectronics. The miniature laser scanners are targeted for 2018. Also other companies have scheduled production of MEMS-based lidars, e.g. Velodyne its Velarray sensor and Osram its 4-channel unit.

Key data for automotive lidar sensors is the range of up to 200 m (objects with a 50-percent reflection) and 0,1-degree of 3D resolutions. The raw data amount is about 6 million pixels per second. This needs to be pre-processed, when it should be transmitted via CAN. Alternatively, the raw data could be sent via proprietary point-to-point connections (e.g. based on Ethernet or USB) within the electronic control unit (ECU).

Figure 1: The Velarray lidar uses Velodyne's proprietary ASICs and comes in a package size of 25 mm x 50 mm x 55 mm; it provides a 120-degree horizontal and 35-degree vertical field-of-view with a 200-m range (Photo: Velodyne)

On the market: lidar units

Continental was one of the early birds in lidar systems. Already in 2012, the Tier1 supplier introduced the SRL 1C lidar device, which could be installed in collision avoidance systems. It features a CAN interface, which is used for configuration as well as sensor state and data transmission. The product is equipped with 16 sensors and provides three thresholds and one hysteresis for each channel. The maximum measured distance for a channel is 14000 mm; the minimum is 1000 mm.

Valeo's partner Leddartech offers the Leddar sensor evaluation kit. It comprises 16 independent segments with simultaneous acquisition and lateral discrimination capabilities. The detection range is up to 50 m. Several beam options are available ranging from 9 degree to 95 degree. The Leddar development software coming with the kit supports CAN, USB, and EIA-485 connectivity. Leddartech cooperates with Integrated Device Technology (IDT). They will jointly develop the LCA2 Leddarcore. This is a solid-state receiver integrated circuit (IC). Built into IC, the patented Leddar signal acquisition and advanced processing algorithms generate a cleaner digital signal and lower detection thresholds compared with other lidar methods to achieve higher ranges and sensitivity at a much lower cost, stated the company. The LCA2 allows automotive OEMs and Tier-1 suppliers to rapidly develop and achieve the high-volume production of optimized 2D- and 3D-lidars aimed at volume prices below €100 using readily available optoelectronic technologies.

In application: not just in cars

The recently introduced Audi A8 is one of the first cars using lidars in combination with cameras and radars giving the car a 360-degree awareness. The car complies with SAE's Level 3 for autonomous driving. It will be available in 2018. Valeo is the supplier of the lidar units and Nvidia provides the central computer to process sensor inputs and to make driving decisions. In case, the A8's emergency assist is activated due to no reaction of the driver (after visual and acoustic warning plus multiple bake jolts with flashing of the hazard warning light), the active lane assist takes over. It moves the car to the road's shoulder and parks it there. Finally, it activates also the park brake. Other carmakers have demonstrated the usage of Lidar sensors in prototype vehicles. Ford recently drove autonomously its Ford Fusion Hybrid in the night on road in the desert, guided only by lidar systems without cameras. The lidar has been developed jointly with Velodyne.

Since many years, automated and automatic guided vehicles (AGV) and unmanned aerial vehicles (UAV) are equipped with lidars. Also in industrial applications such as high-bay storage systems, lifting gears, crane systems, side-tracking skates and truck storage vehicles as well as transfer machines distance measuring devices with lasers are applied. One of the industrial laser scanner provider is Micro-Epsilon. Its Scancontrol 2D- and 3D-sensor family measures 2,5 million points per second. Via Ethernet or ModbusTCP it can be connected to an external host controller or a PC.

Leuze, for example, offers the OMS2/1XX series of laser sensors featuring CANopen connectivity. The device complies with the CiA 406 profile for encoders. Last year, the CiA nonprofit association has released the CiA 462 profile for item detection devices. It standardizes the communication interface for obstacle detecting devices such as lidars, but could also be used for camera-based devices. Pepperl + Fuchs provides also laser sensors measuring distances with CANopen connectivity. The OMD6000-R2100 multi-ray LED scanner uses a proprietary device profile.

Sick is another industrial lidar pioneer. The company developed such laser sensors for non-automotive applications. They are based on Ibeo's lidar technology. The LD-MRS (laser measurement sensor) by Sick comes optionally with one or two CAN interfaces. It can be integrated into AGVs and UAVs. The product connected to a drone demonstrated a working range of 300 m. Even with black objects and just 10-percent re-emission, the range is still 50 m. In a ▷

Figure 2: The lidar evaluation kit comes with a CAN interface and has been designed for industrial applications, e.g. moving robots (Photo: Leddartech)

project, even the black tailcoat of penguins turned toward the drone was registered. The 3D-lidar sensor captures the environment without any gaps and, due to the integrated object tracking feature, reduces the time taken to count the animals across the large population area from several weeks to just a few hours. By the way, lidar units for drones are as price-sensitive as for cars. Seeed Studios offers its RP-Lidar for about €400, which is still not cheap.

The future: stand-alone, but integrated

The development of automated and autonomously driving vehicles is the driving force of lidar technology. The business seems to be huge: Markets-and-Markets estimated a €5-billion turnover for 2022. Others are more conservative: €0,9 billion in 2022 (Allied Market Research), €1,1 billion in 2023 (Global Market Insights), and €1,34 billion in 2024 (Grand View Research).

Anyway, it is a big business. Lidar is one of the key technologies for automated driving. Investors open their wallets for start-up companies such as Tetravue in California – this includes Tier1s and even OEMs, which invests or partners with innovative companies. Investors include Foxconn, Nautilus Venture Partners, Robert Bosch Venture Capital, and Samsung Catalyst Fund.

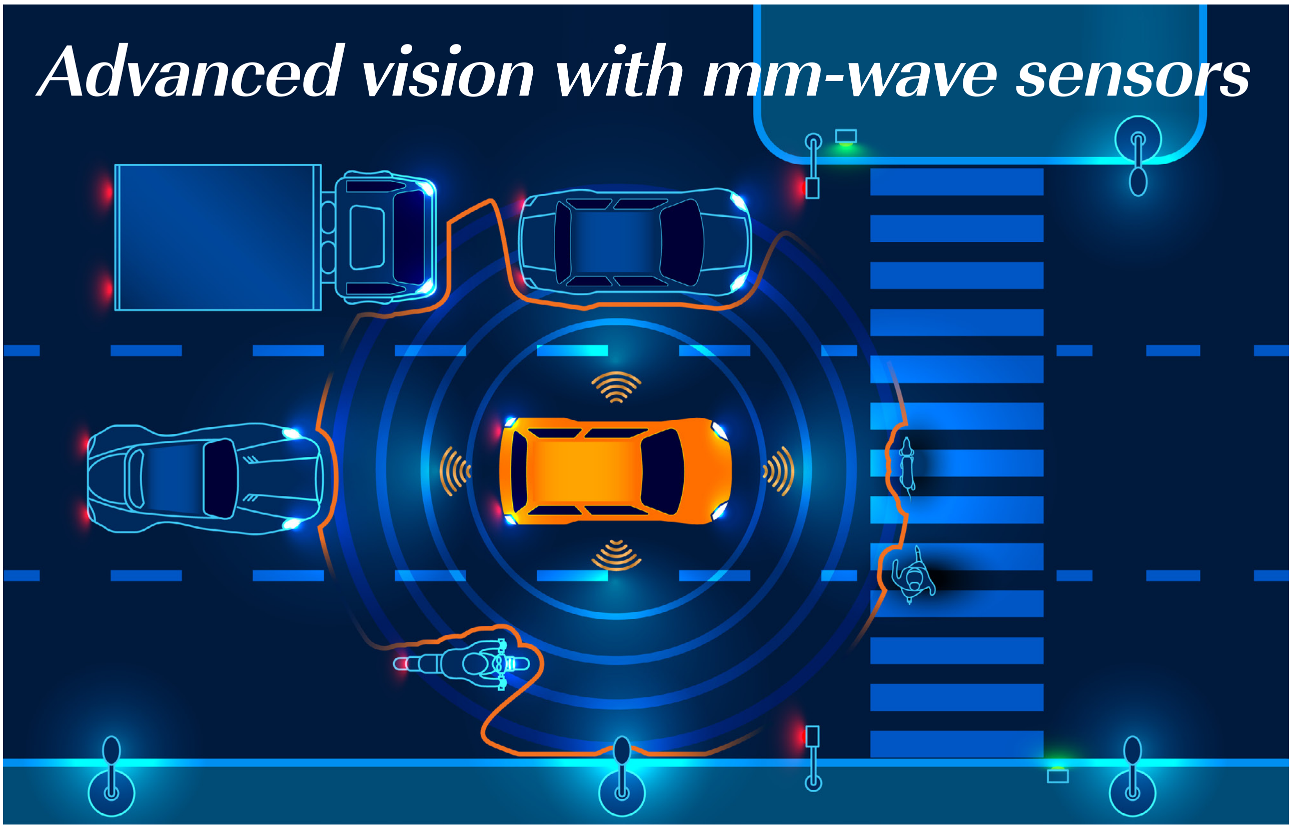
Lidar systems require as its sisters, camera and radar, a lot of bandwidth, which is not provided by the traditional in-vehicle network technologies. Of course, this bandwidth is only necessary for ADAS internal purposes. The results of the environment monitoring and observation are simple: maneuver the car in a safe position, as the Audi A8 is doing. The automated driving itself requires just a few commands and parameters. Classical CAN can achieve this; even if you require functional safety, CAN FD should provide sufficient bandwidth. However, this is only possible, if the raw sensor data are pre-processed in the ECU-embedded multi-core computers.

Lidar-based units cannot just calculate the distance of objects, but also classify them. They can detect lane edges and they work in daylight and at night in darkness. The applications are very different. This is why different device designers integrate MEMS-based sensors into housings together with processors running dedicated software algorithms. But lidar technology also has its limitations. Radar can recognize a wall and has a longer range and it also works in fog, while lidar and cameras can be confounded. ◀

Author

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

Advanced vision with mm-wave sensors



(Photo: Fotolia)

Compact millimeter-wave sensors with integrated CAN modules are suitable for advanced driver assistance systems (ADAS). Texas Instruments (TI) has introduced the mm-wave family, which includes the CAN-connectable AWR1642.

Millimeter-wave sensors are not new. In the past, they were all discrete – with the transmitters, receivers, and the processing components as separate circuits. This made the design process of such sensor complex and the solution big and bulky.

As the number of radar sensors in vehicles climbs to at least 10 (front, rear, and corners), space constraints dictate that each sensor becomes smaller, consumes less power, and is more cost-effective. Some current radar systems under development will push the integration of the transmitter, receiver, clock, and baseband functionality into a single chip, which will reduce the number of front-end chips from four to one.

TI has taken integration to the next level, leveraging complementary metal-oxide semiconductor (CMOS) technology to integrate intelligent radar front ends with embedded micro-controllers (MCUs) and digital signal processing (DSP) capabilities. Processing is co-located with the front end to minimize radar system size, power, form factor and cost, further enabling the mounting of multiple radar systems in vehicles. Classical advantages of CMOS technology include higher transistor density and lower power consumption. Digital scaling in CMOS decreases the power and size and increases performance at every node. Driven by these digital transistor improvements, the speed of CMOS continues to increase and is now sufficient for 79-GHz ADAS applications. The 79-GHz band offers the 4-GHz bandwidth essential for higher-range resolution. Future radar systems will also need support for short range, with better angular resolution translating to more antennas in the radar systems. TI's sensors in CMOS technology can support this scalability to high-volume mass production.

By bucking the trend of traditional SiGe-based sensor technology, TI's RFCMOS-based radar sensors bring in a high-level of digital and analog integration to enable high-output power, low-power consumption (50 percent less compared to existing solutions in market) and low-phase noise, in turn resulting in accurate and ultra-high resolution.

TI's sensor family works on frequency modulated continuous waveform (FMCW) technique in the 76- to 81-GHz band. It has the following features:

- Closed-loop PLL (phase locked loop) enables linear and highly precise chirps, which helps with increased range accuracy;
- Ability to sweep the complete 4-GHz chirp bandwidth, which enables detection of objects spaced less than 5 cm apart;
- A complex receiver architecture that enables jamming or interference detection in a dense sensor environment;
- An intelligent self-monitoring system that self-calibrates across voltages and temperatures.

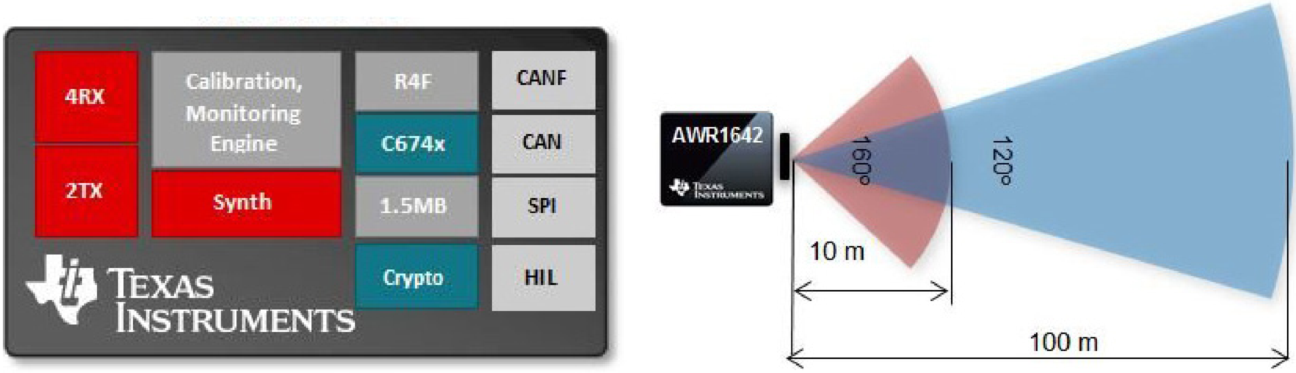


Figure 1: Functions in the AWR1642 mm-wave sensor IC includes CAN connectivity (Photo: TI)

Dedicated for low-range applications

According to the Eno Center for Transportation, about 90 percent of car accidents are due to human error; many of the accidents caused by driver distraction. Cameras, 24-GHz radars, and ultrasonic sensors exist on the market to help address these problems, but the products may not be the best fit. The AWR1642 77-GHz single-mm-wave sensor with an integrated DSP (digital signal processor) (DSP) can work under any environmental condition like day, night, snow, rain, fog, and dust. It offers the below advantages compared to a 24-GHz sensor:

- 33 percent smaller form factor
- 50 percent less power consumption
- 10 times more range accuracy
- Cost-optimized bill of materials (BOM)

The AWR1642 comprises two transmitter and four receiver antennas targeted toward short-range and ultra-short-range applications like blind-spot detection, lane-change assistance, cross-traffic alert and stop and go. It comes with an on-chip ISO CAN FD module and SPI interfaces. The integrated circuit (IC) features 1,5 MiB of RAM, one Cortex-R4F processor, and one C674x DSP. The supplier has published a "short range radar reference design" document.

The presence of a hardware-in-loop (HIL) interface enables feeding of raw analog-to-digital converter (ADC) data collected in the field back to the sensor, which enables the analysis of the data path and algorithmic development. A crypto accelerator encrypts object/raw data sent to the engine control unit (ECU) through the ISO CAN FD interface. ▷

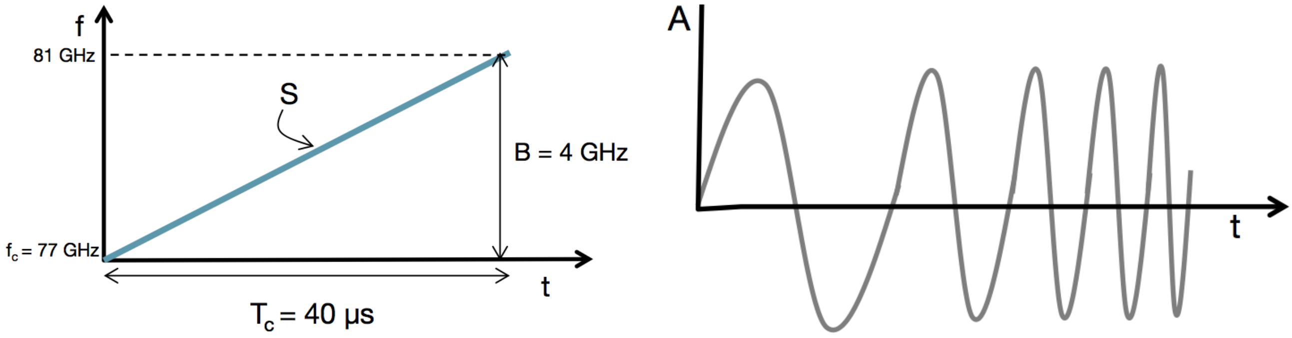


Figure 2: Chirp signal with frequency (left) and with amplitude (right) as a function of time (Photo: TI)

The Cortex-R4F can run Autosar middleware clustering and tracking algorithms. For signal processing-intensive applications like FFT (Fast Fourier Transform) and object detection, the DSP can perform both fixed- and floating-point operations.

Fundamentals of millimeter-wave sensors

Millimeter-wave is a special class of radar technology that uses short wavelength electromagnetic waves. Radar systems transmit electromagnetic wave signals that objects ▷

Advanced driver assistance systems (ADAS) save lives

According to government agencies like the National Highway Traffic Safety Administration, more than 30 000 people in the United States and 1,3 million people worldwide die in road crashes every year; about 94 percent of these crashes are related to human error. An ADAS that helps with warning, breaking, monitoring, and steering can assist drivers and potentially reduce errors. Many vehicles today boast features including blind-spot and lane-departure warning, forward collision and rear cross-traffic warning, automatic emergency breaking, lane-keep assist as well as adaptive cruise control. While these features differentiate brands and are revenue sources for automakers, several countries are now mandating that all vehicles must be equipped with ADAS by 2020.

The demand for ADAS is growing rapidly, owing to a rising awareness of safety, an influence of regulations and original equipment manufacturer (OEM) safety ratings. According to the global ADAS market forecast from Research and Markets, around 50 million vehicles equipped with ADAS were shipped in 2016; these shipments should reach 60 million by 2022. Shipments of ADAS components are expected to increase from 218 million units in 2016 to 1,2 billion units in 2025, according to another ADAS market forecast from Research and Markets. A typical ADAS incorporates various sensing technologies along with advanced processing and communication capabilities to automate, adapt, and enhance vehicle systems for safety and better driving. Automakers rely on leading semiconductor suppliers to provide automotive electronics ranging from advanced sensing technology and imaging/vision technology to high-performance and low-power processors and in-car networking.

The maturity and advancement of ADAS will eventually enable semi-autonomous and autonomous vehicles. Sensing systems are very critical to ADAS and automated driving since they add intelligence to a vehicle, creating an accurate perception of the surrounding environment. Multiple image sensors in ADAS are becoming standard, but newer sensing technologies such as radar, laser, ultrasonic, infrared, and lidar are all enhancing ADAS.

The automotive industry prefers radar sensors, since the sensor penetrates nonmetal objects such as plastic, clothing, and glass and is generally unaffected by environmental factors such as fog, rain, snow, and bad or dazzling light. Automotive radar systems can be divided into short-, mid- and long-range radars, based on the range of object detection; ultra-short range radar (USRR) is also simple vehicle control actions. While current long-range radar (LRR) systems use the 76- to 77-GHz frequency, as higher levels of automated driving require higher range and resolution, front radar systems will likely use both the 76- to 77-GHz and 77- to 81-GHz frequencies for a combination of LRR and newer mid-range radar (MRR) systems. Higher levels will require radar sensors to analyze the complex scenarios by detecting hazards, measuring properties of the hazards (distance and velocity), and categorizing them into objects with distinct properties (distance, velocity, angle, height). Finally, the sensors will need to assist with safe maneuvering.

TI's AWR1x mm-wave sensor portfolio helps developers to create a safer and an emerging ADAS application for park-assist easier driving experience.

Driver-assist features such as blind-spot and lane-departure warning use short-range radar (SRR) systems. These systems are expected to report or warn drivers using light-emitting diodes (LEDs) or steering-wheel vibration. While current SRR systems use the 24- to 29-GHz frequency, according to industry experts, that may well phase out in the future because of regulations around output power at lower frequencies.

Driver-assist features such as adaptive cruise control and automatic emergency braking use LRR systems.

(Source: TI's smart sensors designed for automated driving applications by Sneha Narnakaje. Texas Instruments, 2017)

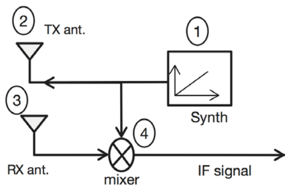


Figure 3: FMCW block diagram (Photo: TI)

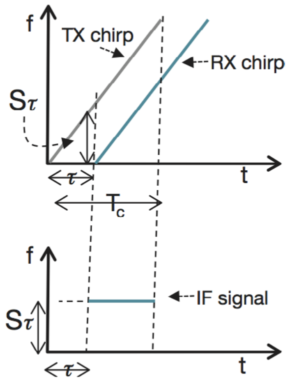


Figure 4: IF frequency is constant (Photo: TI)

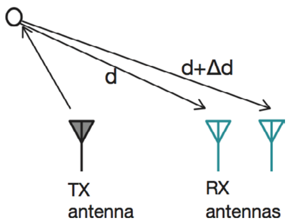


Figure 5: Two antennas are required to estimate the AoA angle of arrival (Photo: TI)

in their path then reflect. By capturing the reflected signal, a radar system can determine the range, velocity, and angle of the objects. They transmit signals with a wavelength that is in the millimeter range. Indeed, the size of system components such as the antennas required to process mm-wave signals is small. Another advantage of short wavelengths is the high accuracy. An mm-wave system operating at 76 GHz to 81 GHz (with a corresponding wavelength of about 4 mm), has the ability to detect movements that are as small as a fraction of a millimeter.

A complete mm-wave radar system includes transmit (TX) and receive (RX) radio frequency (RF) components; analog components such as clocking; and digital components such as ADCs, MCUs, and DSPs. TI products implement a special class of mm-wave technology called FMCW. As the name implies, FMCW radars transmit a frequency-modulated signal continuously in order to measure range as well as angle and velocity. This differs from traditional pulsed-radar systems, which transmit short pulses periodically.

The fundamental concept in radar systems is the transmission of an electromagnetic signal that objects reflect in its path. In the signal used in FMCW radars, the frequency increases linearly with time. This type of signal is called a chirp. Figure 2 shows a representation of the chirp signal with magnitude (amplitude) as a function of time on the right. On the left, Figure 2 displays the same chirp signal with frequency as a function of time. The chirp is characterized by a start frequency (f_c), bandwidth (B), and duration (T_c). An FMCW radar system transmits a chirp signal and captures the signals reflected by objects in its path. Figure 3 represents a simplified block diagram of the main RF components of the FMCW radar; Figure 4 shows IF frequency.

Cesar Iovescu from TI describes in detail in his white paper “The fundamentals of millimeter sensors”, how the radars operate:

- The synthesizer (synth) generates the chirp signal;
- The transmit antenna (TX ant.) sends the chirp signal;
- The reflection of the chirp signal by an object generates the reflected chirp signal captured by the receive antenna (RX ant.);
- The “mixer” combines the RX and TX signals to produce an intermediate frequency (IF) signal.

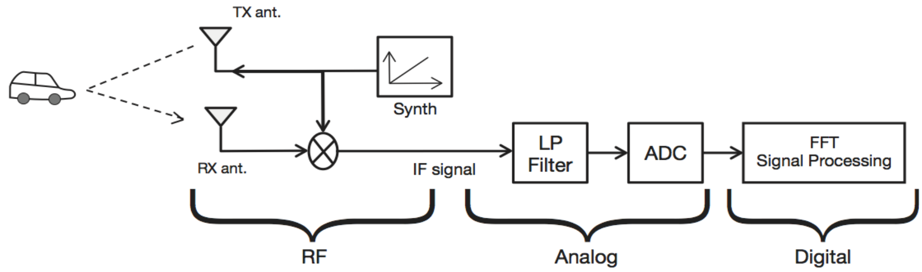


Figure 6: RF, analog, and digital components of an FMCW sensor (Photo: TI)

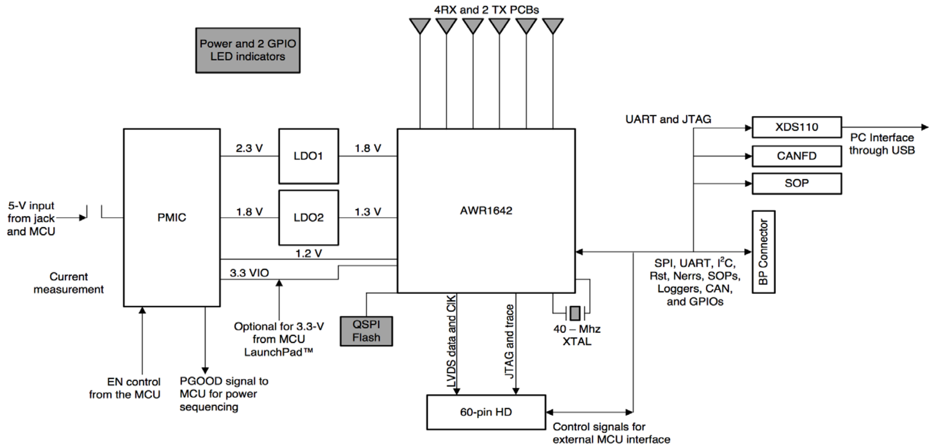


Figure 7: Typical example, how to use the AWR1642 mm-wave sensor (Photo: TI)

The frequency mixer is an electronic component that combines two signals to create a new signal with a new frequency. The operation of the frequency mixer can also be understood graphically by looking at TX and RX chirp frequency representation as a function of time (Figure 4). The upper diagram shows TX and RX chirps as a function of time for a single object detected. Notice that the RX chirp is a time-delay version of the TX chirp. To obtain the frequency representation as a function of time of the IF signal at the output of the frequency mixer, subtract the two lines presented in the upper section of the figure. The distance between the two lines is fixed, which means that the IF signal consists of a tone with a constant frequency. The IF signal is only valid in the time interval, in which both the TC chirp and the RX chirp overlap. The mixer output signal as a magnitude function of time is a sine wave, since it has a constant frequency.

When multiple objects are detected, each chirp is delayed by a different amount of time proportional of the distance to that object. The different RX chirps translate to multiple IF tones, each with a constant frequency. Using a Fourier transforms, this IF signal (consisting of multiple tones) can be processed. This separates the tones and results in a frequency spectrum that has separate peaks for the different tones.

When two objects move closer, at some point, a radar system is not able to distinguish them as separate objects. Fourier transform theory states that you can increase the resolution by increasing the length of the IF signal. To do so, the bandwidth needs to be increased proportionally. Thus the FMCW radar with a chirp bandwidth of a few GHz has a range resolution of some centimeter (e.g. a 4-GHz bandwidth translates to a range resolution of 3,75 cm).

In order to measure velocity, the FMCW radar exploits phase change across chirps separated in time. The FMCW radar transmits a set of N equi-spaced chirps called a frame. Each reflected chirp is processed by a first FFT, called range-FFT, to detect the range of the object. A second FFT, called doppler-FFT, is performed to determine the velocity. Velocity resolution defines the ability to distinguish between two different speeds. The shorter the frame length, the higher the velocity resolution. Since velocity is computed based on phase change, there is an ambiguity. Maximum velocity that can be unambiguously measured is inversely proportional to the time Tc between consecutive chirps.

An FMCW radar can also estimate the angle of a reflected signal with the horizontal plan. This angle is called angle of arrival (AoA). Angular estimation is based on the observation that a small change in the distance results in a phase change in the peak of the range-FFT or Doppler-FFT. Using two RX antennas, you can measure the differential distance from the object to each of the antennas. The phase change enables you to estimate the AoA.

To summarize, an FMCW sensor is able to determine the range, velocity, and angle of nearby objects using a combination of RF, analog, and digital electronic components. The block diagram of TI's single-chip mm-wave sensor shows the necessary components. The sensor is able to store 512 chirps with four profiles before a frame starts. This capability allows the product to be easily configured with multiple configurations to maximize the amount of useful data extracted from a scene. Individual chirps and the processing back-end can be tailored "on-the-fly" for real-time application needs such as higher range, higher velocities, higher resolution, or specific processing algorithms.

Of course, the AWR1642 is not only suitable for applications in passenger cars, but also in commercial vehicles including mobile machinery and in other self-moving systems including service robots and automatic guided vehicles. For low-volume applications, a standardized CANopen or J1939 profile would simplify system integration. ◀

Author

Holger Zeltwanger
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

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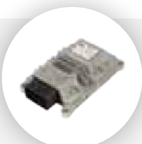
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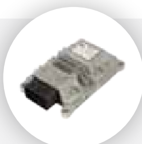
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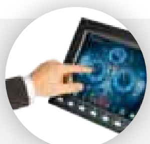
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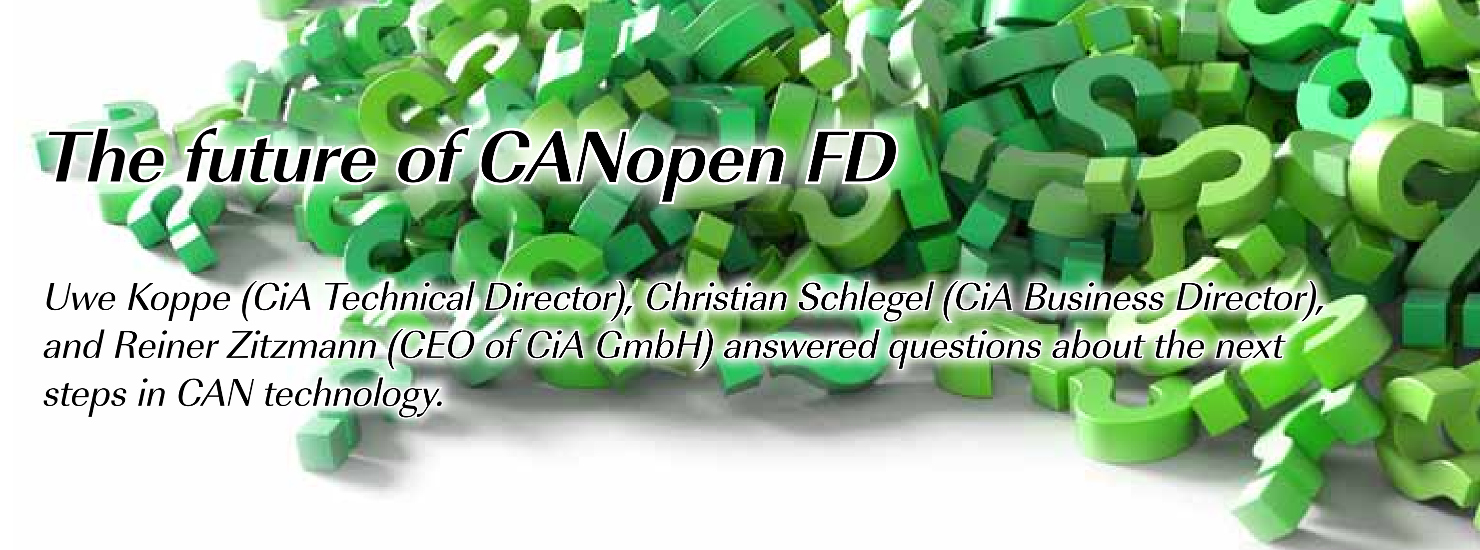


The future of CANopen FD

Uwe Koppe (CiA Technical Director), Christian Schlegel (CiA Business Director), and Reiner Zitzmann (CEO of CiA GmbH) answered questions about the next steps in CAN technology.

With the introduction of CAN FD, the CAN community has improved the Classical CAN protocol providing more bandwidth (today: up to 5 Mbit/s) and larger payload (up to 64 byte per data frame). First CAN FD controllers and transceivers qualified for 5 Mbit/s are available. CiA develops higher-layer protocols using the CAN FD lower-layers. The CiA 602-2 specification describing the mapping of J1939 messages on CAN FD frames is already released. CiA 301 specifying the CANopen FD application layer and communication profile will be released very soon.

CAN Newsletter: The CAN FD lower-layers have been internationally standardized and CiA has released some first design recommendations (CiA 601 series). What is still missing for the non-automotive users?

Koppe: From my point of view a design guideline needs to be developed which recommends combinations of arbitration and data phase bit-rates along with topology limitations (e.g. maximum stub length). This would allow users to evaluate an upgrade path for existing networks as well as having a specification for the next generation of machines.

Schlegel: When using Classical CAN, the users have been used not to think about the physical parameters of the cable. More or less just any cable was good enough. With CAN FD and its higher data rates the cable becomes an essential component in a network installation. The impedance is important and due to this the isolation material which physical parameters should be more resistant against humidity and temperature. Here we need clear specifications and CiA should also work with the cable manufacturers in order to make these cable types available as standard CAN FD cables.

Zitzmann: From a specification point of view, comprehensive implementation guidelines and application notes for system design and device design are still missing. System designers would appreciate a detailed cable specification as well. This is why CiA has started several initiatives to develop such kind of documents that enable system designers and device designers to introduce CAN FD in their applications. From a user's point of view, we are on a very early stage. Suitable CAN FD hardware is just available for the developers. So a broad range of device and tool manufacturers have just started to introduce CAN FD in their products. Availability of suitable devices and network components is a prerequisite for system designers to consider CAN FD in the next generation of their applications.

CAN Newsletter: CANopen FD is in the pipeline and will be released soon. What are the main benefits compared to classic CANopen?

Koppe: I can imagine that most people rank the speed and the greater payload of CANopen FD first, especially when you have seen the CANopen FD demonstrator on the Embedded World fair. However, I believe the main benefits are a more comprehensive specification in combination with additional functionality, e.g. the error history has been revised. But the biggest advantage is the new USDO service, which allows unicast, multicast, and broadcast communication between CANopen nodes. Hence it is now possible to transfer data to all CANopen nodes in a network using only one request.

Schlegel: First of all CANopen FD benefits from the improvements of CAN FD compared to Classical CAN. CAN FD brings a performance improvement by two major modifications: first the increase of the maximum length of a message from 8 data bytes to 64 data bytes (which is also reflected in the revised PDO specification of CANopen FD), and second the increase of the maximum data rate from 1 Mbit/s up to 10 Mbit/s during the transmission of the payload data. As a side effect, the residual error probability of CAN FD could be even lowered compared to Classical CAN. Another major improvement in CANopen FD is the introduction of a new SDO service and protocol called Universal Service Data Object (USDO) which enables the efficient use of the longer CAN messages but also provides much more functionality like routing in different CANopen FD networks.

Zitzmann: I think CANopen FD is just to be considered as an add-on to the Classic CANopen. It saves the advantages of todays well established CANopen and keeps therefore all its attributes such as the clear device architecture, high design flexibility, and the feasibility on very robust hardware platforms by demanding a very low power consumption. On top of this, CANopen FD allows meeting the requirements of tomorrow's embedded networking, by making use of the increased data throughput that is provided by the new CAN FD data link layer. Lengthened PDOs allow a rapid transport of large amount of process data. On the one hand this eases meeting the increased demand for data by con- ▷

dition monitoring or predictive maintenance applications. On the other hand especially safety and security applications will benefit from the lengthened data field. The process data can be enhanced by safety or security signatures in a single CAN FD data frame. In more and more applications the system is not static but the end user modifies the system by adding or removing devices to/from the system. The new and highly flexible USDO meets the therefore required dynamic establishment of device cross-communication between the devices easily. During system runtime and without any pre-configuration, any CANopen device is enabled to communicate in unicast and broadcast with any other CANopen device that is connected to the entire CANopen system architecture. This even applies, if this CANopen system architecture consists of several CANopen networks, interconnected via CANopen-to-CANopen router devices.

CAN Newsletter: What are the next steps to make CANopen FD as successful as classic CANopen in different application fields?

Koppe: A good marketing campaign, which includes workshops and training for CiA members.

Schlegel: It is absolutely important that the semiconductor manufacturers provide micro-controllers with CAN FD support which are suitable for the non-automotive applications and markets. There are already several micro-controllers with CAN FD support available today, but they are mainly targeting more complex applications and ECUs in cars and therefore also provide interfaces and features which are not required in many devices for non-automotive applications but make the micro-controllers much more expensive. Preferably the existing families of micro-controllers with CAN support ranging from very small versions to more comprehensive versions should be enhanced with CAN FD support. Basically this is like the chicken and egg question – who came first. Once the right micro-controllers are available, CANopen FD probably can become a self-runner because it will provide many advantages for non-automotive applications compared to classic CANopen: higher band-width, possibility for longer network extensions, improved services (e.g. longer PDOs, USDO) and better management of the conformance of the CANopen FD devices.

Zitzmann: From a specification point of view, we have to adapt all the existing CiA CANopen specifications to CANopen FD. For any specification we have to keep as many CANopen aspects as possible stable but adapt them where necessary and beneficial. This is quite a lot of work. The most urgent documents are the XML-based device description (CiA 311) as well as the conformance test plan (CiA 310). But also an adaptation of specifications such as CiA 302 (network management functions), CiA 305 (layer setting services), and CiA 309 (external access to CANopen) is in the focus. CANopen FD users will demand for efficient usage of ▷

Uwe Koppe (Microcontrol) *Christian Schlegel (HMS)* *Reiner Zitzmann (CiA)*

the lengthened PDOs, according to updated CiA device and application profiles. Therefore we have to start updating our CiA device and application profiles, as well.

From a marketing point of view, CiA is going to inform the public on the possibilities, offered by CANopen FD. A good option in this context is the CANopen FD demonstrator, jointly developed by our CiA member companies. The CiA community has to come up with CANopen FD devices and tools, so that CANopen FD becomes an interesting candidate. Some people may think that it could be a show-stopper that for the moment, no big host controller manufacturer considers CANopen FD. But most of them have host controllers with CAN or even CANopen support. So as soon as a specific host controller supports CAN, we can assume that there will be automatically CAN FD capability in future. To make such a host controller CANopen FD capable, only the integration of a CANopen FD protocol stack is required. CANopen FD protocol stacks are available even today, and have already been demonstrated on occasion of the SPS IPC Drives 2016 and the Embedded World 2017, as part of our demonstrator, in a multi-vendor system.

CAN Newsletter: Will CANopen FD networks compete against Ethernet-based solutions?

Koppe: The hardware price for an Ethernet-based solution is roughly three to four times more than for a CAN FD solution. You also have to consider the much higher memory requirements (Flash and RAM) and power consumption for Ethernet-based solutions. However, Ethernet has a higher data throughput. So it is not a question of competition, both networks will coexist peacefully because of different application requirements from the market.

Schlegel: For sure there will be some markets and applications where there is an overlap and both technologies will compete. However on the major market for Ethernet-based networks, which is factory automation, where large machines are controlled by Industrial Ethernet networks, have strong requirements for motion control and where the machines are also interconnected in production lines on the factory floor, (Industrial) Ethernet is set.

CAN FD and therefore CANopen FD has some quite specific strengths compared to the different (Industrial) Ethernet standards which make it more interesting and suitable for certain non-automotive applications. Examples of its strengths are robustness (MTBF, error rate, EMI immunity), it's a bus system (no active switches between the components are necessary), installation and maintenance, power consumption (typically 3 times less than a standard Ethernet interface) and price (3 to 5 times less than an Ethernet interface considering the interface and the micro-controller performance including memory size).

Zitzmann: For any kind of application, there is always the question, which kind of communication system meets the requirements of this application in the best way. On the one hand there are technical criteria such as robustness, supported topologies, power consumption, power-on times, communication speed, latency times, cycle times, etc. On the other hand there are business criteria such as availability of devices, components, and support from several sources for reasonable prices. So after analyzing technical and business criteria for a specific application, the synopsis will show also in the near future that CANopen FD is a good candidate for realizing embedded and deeply embedded applications. My expectation is, CANopen FD and industrial Ethernet will complement each other. CANopen FD is closing the gap in data throughput between classic, so-called "fieldbus systems" and backbone applications, based on industrial Ethernet.

CAN Newsletter: Do you think that there is a need to make CANopen (FD) a thing in the Internet? Are there any activities of CiA to do so?

Koppe: In order to get data from CAN (FD) to the Internet you will need a gateway, which typically has knowledge about the underlying network, including the object dictionary of all CANopen (FD) nodes. Hence we need to define IoT methods for accessing this data.

Schlegel: In order to answer this question we first have to discuss what is meant when referring to Internet of Things. In my opinion it is a buzzword used for many different things and topics. In the scope of industrial control and networking in non-automotive applications I see two major use-cases relating to CANopen (FD) and the Internet of Things: data exchange between the IT and the OT (Operational Technology) world by means of gateways or edge controllers and the collection of additional diagnostic and operational data from the individual devices in the network. Basically there exist two protocols which are strongly related to these use-cases: OPC UA and MQTT. Both protocols are TCP/IP based and can therefore not directly be used with CANopen (FD). Anyhow, in order tunable a link between CANopen (FD) and the Internet of Thing a specification is required defining how OPC UA or MQTT are mapped to CANopen (FD). This is done by so-called companion specifications. A CiA working group is already working on an OPC UA / CANopen (FD) companion specification.

Zitzmann: More and more added values are generated by web-based applications. Predictive maintenance, condition monitoring, individualization, and optimization of a product, based on tracked user-behavior are just a few examples of big data applications. Although embedded systems such as CANopen are not in the focus of these big data applications, they provide the database for the big data applications. However not any CANopen sensor has the requirement to be connected to the Internet, there has to be the general ability to do so. To ease the access to embedded devices from point of view of a web-based application, a standardized workflow and the usage of standardized data formats are very advantageous. CANopen supports this already by its standardized CANopen device architecture and the standardized application data, specified in various device and application profiles. Additionally, CANopen supports already standardized CANopen access services that allow a simple to use access to embedded CANopen networks, from TCP/IP-based networks (CiA 309). In general CANopen (FD) is already well equipped to make CANopen a part in the industrial Internet of things (IIoT). To put all the existing CiA specifications together to a harmonized workflow, the CiA working group "SIG CANopenIoT" has been established. The group evaluates how CiA 309 commands are usable with existing and well-established web services, based on Restful, HTTP, Websocket or MQTT. Furthermore the group considers discovery functions that provide an overview, which kind of functionality resides in an embedded CANopen network. In this context, the group has introduced a reference designation system, derived from the IEC 81346, to allow a logical addressing. This may free end users of the necessity to know any CANopen specifics, in case they would like to have an access to a CANopen system's function or parameter.

In a connected world, we shall not forget on security issues. In the past we could always assume that CAN-based systems are deeply embedded and not accessible by unintended actors. But these days are gone. Opening an embedded system to the world opens the door to misuse of the application, as well. To avoid the unintended access to a CANopen (FD) system, CiA has established the working group TF security. This working group is analyzing the security functions available in the market as well as the security requirements in the various ▷

CANopen applications. Based on these results, the group is developing harmonized solutions to meet the particular security requirements.

By the way, both groups appreciate contributions in form of technical comments or submissions. Groups can just consider requirements and solutions, of which they are aware. So I would like to take the opportunity and to invite experts in the aforementioned topics, to take part in CiA's working groups. Many meetings are organized as web-meetings. Therefore participation is rather simple and may be beneficial not only for the emerging specification but also for the personal networking.

CAN Newsletter: What is your view on the future of CAN-based solutions in non-automotive applications?

Koppe: The market for CAN and CAN FD will increase in future, because the bus offers a reliable and robust communication at the lowest possible cost. In addition it is quite easy to develop safety applications according to EN 50325-5. And finally the increased payload allows secure communication, a topic that is already in focus for non-automotive applications.

Schlegel: Also in the future, we will still see CAN-based networks in many areas. Based on the already mentioned strengths of CAN FD / CANopen FD, there are several markets and applications like health care, regenerative energy, transport (ships / vessels, trains, air crafts), „small machines" (e.g. ticket machines, vending machines, handling systems), automation system in buildings (elevators, escalators, door control), small robots, utility vehicles, and especially everything which is battery operated. As in many of these areas simple serial interfaces are still used in manifold ways and CAN would bring considerable improvements to such systems we can expect that the use of CAN will become even broader. Besides of this, all car manufacturers confirm consistently that they will continue to use CAN FD in the future and CAN FD will not be replaced by Ethernet.

A major exception is the factory automation market. Here the Ethernet based systems have major advantages compared to CAN / CAN FD. However, for smaller units or sub-systems inside these machines CAN or CAN FD might still be the better and preferred choice.

Zitzmann: The automotive industry is just introducing CAN FD and is planning in long-term to substitute classical CAN by CAN FD. Due to the high volumes of CAN FD that are expected to be installed in the automotive industry, CAN FD will be supported on many MCUs. Therefore, for the next decade, CAN will be available also for the non-automotive market. This is why – as any "CAN FD controller" is able to communicate Classical CAN – CAN will remain an interesting candidate for non-automotive applications. But this means also that many of todays CAN users will get CAN FD capable hardware, even if they just use for the moment the Classical CAN functionality. Some day, they will recognize that they can meet their tomorrow's requirements on embedded networking, e.g. just by replacing the CANopen protocol stack by a CANopen FD protocol stack. This CANopen FD stack makes use of the CAN FD functionality of the already available CAN hardware. This way, with a minimum effort, the embedded CAN is "ready for future" by reusing the existing topology and without a huge training effort of the involved device and system designers. ◀

Interviewer

Cindy Weissmueller
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org


Visit us at
SPS/IPC/Drives 2017
hall 7A · stand 7A-302
Lufthansa LEOS

Connectivity for mobile systems

This article describes how mobile CAN-based systems and machine-on-wheels can be connected to the Internet

Figure 1: Smartphones are increasingly used to provide Internet connectivity for mobile CAN-based systems (Photo: Moba)

If you have not heard buzz words like Internet of Things (IoT), Machine-to-Machine communication (M2M), or Industry 4.0 you might have spent the last few years on Mars or in an information black out. With the emergence of the Internet and low-cost data transmission possibilities, we started to connect a wide range of things (like sensors, machines, etc.).

But not only on the technical side, we as humans also adapt rapidly to this era. In fact, there is already a term for digital natives: Generation C. Members of this generation connect to people and things in ways not imagined in the past. Social media, gadgets, and wireless technology allow Generation C to share data on the fly.

This process is often split up into two distinctive parts. First, there is the collection of data. This can be either traditional sensor data like temperature or pictures and videos for social networks. After the collection, most often we are trying to get useful information out of the collected data. With the new wave of smart and self-learning algorithms – here we have a new range of other new buzz words like artificial intelligence or neuronal networks – it feels like we are still in the early stages of turning huge amounts of data into actionable information (this can range from new decentralized weather monitoring and prediction systems to face recognition algorithms). Here, the focus will be on the connectivity aspect of the process or in other words how all these devices can be connected to the Internet and data can be exchanged. Even more specifically on mobile systems with CAN or CANopen networks and how they can connect into the Internet and make IoT and Industry 4.0 reality.

Therefore, we are firstly looking into the current situation, circumstances, and some constraints in which mobile CAN-based systems are operating. Followed by a look into technologies how data from CAN networks can be transported into the Internet. Finally, some connectivity applications scenarios are outlined and how they could be implemented.

Situation

CAN as a central communication technology in mobile systems is widely found. Naming just some representative examples is almost impossible. Our customers operate on- and off-road trucks in various shapes and heavy construction machinery in general. All of these machines and systems rely on one or multiple CAN networks.

Traditionally, these machines and systems have been black sites regarding connectivity. There are CAN networks on the machine itself but there was no need to communicate with the outside world. In the 1990s, mobile phones allowed drivers, operators, and support technicians to connect to the outside world (at least audio) but the systems itself not. According to different predictions, there are today up to 70 % of these machines and systems out silently doing their jobs.

Technology

So, if there are so many machines and systems out there, which might need to become part of IoT, what are the technology options to make this happen?

First of all, there is an architectural or systemic question. Like cars or mobile phones, the first idea could be that every machine has its own access to the Internet. That is definitely true for most of the machines with CAN networks. Trucks in all shapes often operate alone or at least drive routes by themselves. Therefore, a separate connection per machine is necessary. However, there are other cases in which a group or a fleet of machines work together in well-defined areas, like jobsites or mines. In these scenarios, it could be possible that only one machine or system has access to the Internet and all other machines re-use this connection.

Case 1 - Machines with own Internet connection

Let's start with the first case in which each machine has its own Internet connection. The most obvious solution is the use of a mobile network. With the current LTE speed it is possible to reach up to 300 Mbit/s download and 75 Mbit/s upload speed. This should be easily enough to transport data from multiple CAN networks. Even with the older mobile network standard 3G (at least 2 Mbit/s) it should be easily possible to connect machines into the Internet. However, this touches on the topic of coverage. In large cities LTE and 3G (as backup) are widely available. But less populated and rural areas in general have limited or no mobile network coverage at all. For example, there is currently a major motorway (Autobahn) ▷

construction project underway in Germany connecting the cities of Kassel and Eisenach. The motorway leads to larger areas without any mobile coverage, making it difficult to connect to the construction machines on this jobsite. Another point is the set-up and ease of use. Modern solutions cover the complexity in setting up SIM card, providing therefore a good and easy experience for users of such solutions.

To be able to use mobile networks, it is usually necessary to sign a contract with one of the mobile network operators. Here are two important things to mention. Firstly, mobile network operators often separate their networks on country boundaries. So, if machines are used across borders, it might be necessary to check the pricing. Within the European Union roaming costs become a thing of the past, however in other regions of the world, this still needs to be considered. Secondly and related to the first point, mobile network operators charge monthly fees for their services. This is fine for most of the applications, however if the connection to a machine and its CAN networks is only needed occasionally, a monthly fee for mobile network operators is perceived as high costs.

Here, smartphones started to become a major role to provide connectivity even in these cases. Gateways which provide access to CAN networks via WiFi or Bluetooth are connected to the smartphone, which acts as a tethering device or in other words as central access point into the Internet. The advantages and differences between WiFi and Bluetooth are discussed in more detail later on in case 4.

Case 2 – Internet connection via WiFi hotpots

The second option how individual machines and their CAN networks could connect to the Internet is to use openly available WiFi hotspots. Like mobile network coverage, this is most often available in larger cities and it might be difficult to get hold of a WiFi hotspot in rural areas. Notable exceptions are the countries of Estonia and Lithuania, which have – according to several reports – the best and widest-ranging WiFi hotspot networks in the world. Here you might be able to connect to a WiFi hotspot even in rural areas.

Case 3 – Internet connection via satellite-based communication

Finally, it might be possible to use satellite-based communication (e.g. Iridium or Inmarsat) in areas of missing mobile coverage. A prime example is Australia. In most parts of the sparsely populated Outback there is no mobile coverage available. Due to the large distances, there are solutions available in which trucks report important data through satellite-based communication. Unfortunately, the use of satellite communication is very expensive compared to the usage costs of mobile networks.

Case 4 – Internet connection through a central access point

As mentioned earlier, the second architectural option is the use of a central access point to connect into the Internet, which is then re-used by other machines and systems. The central access point faces the same considerations in ▷

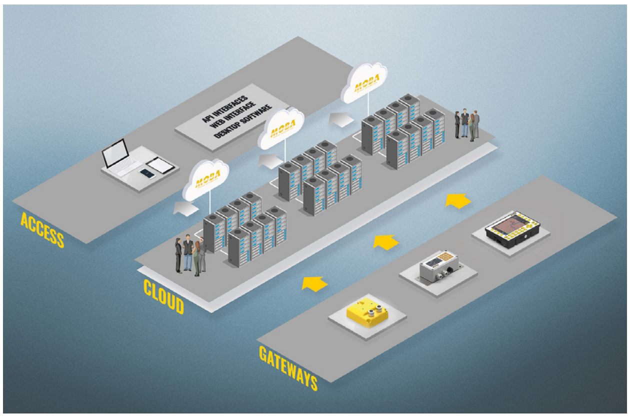


Figure 2: Typical setup to connect mobile CAN-based systems to the Internet (Photo: Moba)

regards how to connect to the Internet as described above. Most often a connection via a mobile network can be a viable solution. But there might be other aspects to consider as well. In such a scenario, there would be only one connection, therefore the costs are limited and it might be possible to use a high-quality and very reliable solution. Also from a risk point, it might be important to focus on reliability as the connection would be the single point of access to a fleet of machines. In other environments like mines, it might also be possible to set-up an additional IT infrastructure to provide connectivity. Here, often WiFi routers are installed, allowing machines access to the Internet.

Besides the central access point, it is crucial how other machines can connect to this access point. The two most common technologies are WiFi and Bluetooth. Both have distinctive features, which can both be suitable technologies for different machines and use cases. Here, five specific characteristics are highlighted.

The first aspect is range. Bluetooth has an intended range from 10 m up to 100 m. In the WiFi world, there are no pre-defined ranges. Here it depends on aspects like transmission power and antennas. To complicate matters, a lot of countries have specific regulations around maximal antenna power output. However, the current distance record is held by the Swedish Space Agency with 420 km (260 miles) – using special equipment. But even with standard equipment it is likely to reach 200 m (656 ft) outdoors. Another aspect is bandwidth. For Bluetooth the maximum bandwidth is 24 Mbit/s. Whereas WiFi allows up to 862 Mbit/s with its newest standard. This is even higher than the current LTE standard.

Related to range and bandwidth is power consumption. It is easily imaginable that WiFi creates a stronger signal (and therefore consuming more power) as WiFi signals need to travel further and with higher bandwidth. A study from the University of California at Los Angeles has shown that in worst case scenarios Bluetooth needs less than 3 % of the power WiFi would need for the same task. Another very interesting and sometimes overlooked aspect is the routing capability of the different technologies. With routing it is possible to send data between different networks. In fact, routing makes (access to) the Internet actually work. Since WiFi is based on the same protocols used in the Internet, it supports routing. Bluetooth usually does not support routing. The most common use case is a so-called point-to-point connection (like a smartphone and hands-free car kit). In other words, it is necessary to convert the data received from Bluetooth, so that it can be used and routed in the Internet.

The last aspect is set-up and ease of use. Even though the people who struggled with a Bluetooth pairing lately, might disagree, but – in general – Bluetooth is easier to set-up. WiFi now has possibilities like WPS, which reduce set-up hassles, however it can get somewhat more complicated with network names (SSID), passwords, network structure, and so on.

Application scenarios and their implementation

After looking through the available technical options to provide Internet connectivity for CAN-based systems, let's have a look at three different application scenarios and how they could be implemented, namely remote support, machine-related data, and production-related data. The three scenarios are described separately here, but often they are used together at a machine or system.

Remote support

Remote support for machines is often the first idea, which comes to mind if it comes to Internet connectivity. Remote Support stands for a wide range of options and possibilities. It could be that a new machine is tested in the field and the engineering department wants to check the machine regularly or if customers report problems with the machine. Another use case could be that the machine is in the early stages of production and the chance of a software or firmware update is high. Or maybe machines are sold worldwide and in some regions of the world the support or dealer network is not as extensive as in the domestic markets. Or maybe the users of the machines manage very time-critical processes and therefore any down-time is extremely critical and expensive. Fixing the problem as quick as possible is therefore crucial. Yet another use case is the possibility to train users remotely. Instead of trying to explain how to use the system on the phone or sending a technician to the user, the screen is shared and the support technicians can remotely train and provide best practice experiences.

Implementing remote support usually means that each machine has its own device or possibility to connect to the Internet. Using the other approach of a central access point might work in some circumstances, however if the access point needs support the whole fleet of machines and systems might also not be connected to the Internet. Due to the wide range of options which are summarized under remote support, the used technology will be different. If the timely access to the machine is highly important, a SIM card solution or in extreme cases even a satellite-based solution are the right choice. On the other end of the spectrum are solutions in which the support can wait until a machine is back in the workshop or yard. The solution here would be that the machine connects via WiFi (through an existing WiFi network) into the Internet. For price-sensitive markets or only occasional accesses to a machine, which do not want to pay a monthly fee to mobile network operators, the solution with a smartphone acting as tethering device is a very interesting solution. ▷

Machine-related data

Machine-related data, as the next application scenario, are somewhat related to remote support, in the sense that support is hopefully reduced due to the usage of machine-related data. These data are characterized as all data which directly belong to a machine. Obviously, this varies with each machine and system, but recurring examples are information about oil (pressure, remaining oil, status of oil filter), remaining fuel, engine status (idle, engine speed) and much more. With these data a wide range of things can be accomplished. To mention a few, the already mentioned support can be better planned. For instance, if an oil filter shows first signs of problems, an exchange can be scheduled and therefore an unexpected failure of the machine in operation can be avoided. Another use case of machine-related data is the monitoring and improvement of machine utilization. If a machine is used only occasionally or not at all, it might be better utilized at a different jobsite, plant, etc. (given that it is not a specialized machine which is needed specifically there). A last machine-related data use case example is the improvement of productivity. For example, if an engine is most of the time idle, it burns a lot of fuel (and creates pollution) and takes hours away from the machine's warranty. Therefore, turning off engines if they are not used can save money and air pollution.

Similar to remote support, the technical implementation depends on the users' requirements. If, for example, a rental company wants to check that a machine is only used within the terms agreed in a rental contract, a solution with a SIM card is most likely suitable. But if the focus is on oil filter status, it might be enough to connect the machines into the Internet as soon as they are back on the yard. If the machine is part of a fleet, the use of a central access point is also a viable solution.

Production-related data

In contrast to machine-related data, production-related data focuses on the processes or tasks the machine is currently working on. A practical example would be fill or cut information from an excavator. Very often excavators are used to fill an area (filling) or remove a pile, hill, dig a whole, and so on (cut). In this case it could be very interesting to know how far the task of filling or cutting is progressed. Another use case could be that the plan changes on what needs to be filled or cut and the updated plan needs to be sent to the operator. In general, the processes and tasks are specific to machines and the applications in which they are used. But there are some recurring patterns which can be identified across a wide range of processes and tasks. Firstly, the degree of task completion is, as already mentioned, very often of interest. Secondly, reports or documentation about the tasks or processes done are important. For example, in road construction the asphalt temperature can be measured throughout the paving process. If the temperature stays within a certain range, it is a proxy for a high-quality asphalt and therefore high-quality roads. Thirdly, any problems or exceptions form the process should be reported; often in form of warnings, errors, and exceptions. Lastly, process or task updates need to be sent immediately to the machine. This could be the already mentioned plan update for excavators but also a wide range of other information and parameters like the maximal boom length of a crane based on current weather conditions.

Implementing the connectivity of production-related data requires usually a constant Internet connection. In this scenario, the use of mobile networks is the dominantly used technology, whether each machine has a separate SIM card or there is a central access point for a fleet of machines (e.g. a WiFi hotspot in a mine). If the process or task is highly critical or creates a lot of value for the user, it might be helpful to use satellite-based communication. It is worthwhile mentioning that production-related data can become large in quantity. Therefore, it is important that there is not only a connection but a connection with enough bandwidth to transfer all the data.

Summary

The Internet of Things and Industry 4.0 are currently filled with life. In this article, we had a look on how mobile CAN-based systems and machines can be connected into the Internet and therefore become part of IoT and Industry 4.0. Depending on the users' needs there are well-established technologies available to connect machines and systems to the Internet. Most prominently is the use of mobile networks either for each machine or as a central access point for a fleet of machines. The use of a smartphone as a tethering device, WiFi, Bluetooth, satellite-based communication also are important technologies for connectivity and might become even more important in the future. All these technologies are used in application scenarios found in mobile machines and systems. These scenarios, namely remote support, machine-related data, and production-related data, represent a wide range of use cases and applications which make IoT and Industry 4.0 reality. ◀

Author

Matthias Limbach
Moba Mobile Automation
mschmitt@moba.de
www.moba-automation.com

CAN automates crop cultivation

The described relatively simple system illustrates how CAN networks could be used to control the environment within a commonplace horticultural application.

Research conducted by the University of Minnesota has estimated that, given that current projections expect the global population to be over 9 billion by 2050, agricultural output would need to increase by approximately 60 percent in order to avoid major food shortages being witnessed within this period. At the same time dwindling oil reserves will mean that biofuel production has to be ramped considerably to keep pace with heightening demand (market analysts at Navigant Research have recently predicted that annual biofuel shipments will rise by around 35 % to 40 % between now and 2020). These two dynamics when factored together will put a great deal of strain on the planet's crop production capabilities. In response, more comprehensive use of technology is going to be needed so as to increase crop yields.

CAN is the dominating in-vehicle network. CAN networks are also used in industrial automation (mainly in embedded front-end units) and building automation (climate control and lighting control systems). CAN presents engineers with an easy to implement, lightweight, error detectable network protocol that is capable of supporting communication at 1-Mbit/s data rates over distances up to 1 km without repeaters. It is, that the implementation of CAN is starting to see substantial uptake within agriculture and horticulture, where an increasing degree of automation is now being mandated. These industries of course generally need large expanses of land on which to grow their produce and often field repair/maintenance could prove to be expensive - so a reliable, far-reaching, very economical networking medium such as CAN displays all the main attributes to make it appealing.

If an agricultural/horticultural automation implementation is to be fully effective, data concerning soil condition, ambient temperature and humidity levels needs to be continuously acquired, in order to ensure that these key environmental parameters are maintained at optimal level to maximize crop production. In addition, light sensors can be used to monitor how well the crop is being illuminated in different areas. Once all this data has been transported back it can be analyzed and actions taken if needed. By way of an example let's take a large greenhouse. If the light levels in a particular area were consistently found to be lower than elsewhere in the building, the LED lighting at that location could be turned up to provide greater illumination and thereby encourage great photosynthesis to occur. Furthermore, if analysis suggests that alteration of the light wavelengths will be advantageous in terms of crop growth then the balance of RGB-LEDs can be altered accordingly.

With regard to a large outdoor agricultural facility, if data retrieved suggested (for instance) that the soil's moisture content was too low, the operative examining these figures could subsequently initiate the carrying out of additional water spraying to alleviate the issue.

The benefits of greater automation in agriculture and horticulture are clear. There is a problem, however, that needs to be overcome if its more extensive proliferation is to be secured in an acceptable timeframe. This is having the electronic hardware available that can firstly cope with all the fairly heavy data processing involved in a cost-effective manner and then; secondly, have the connectivity features that are required.

The shown example in Figure 1 illustrates how a CAN-based infrastructure may be used to control the environment within a commonplace horticultural application. Here parameters such as soil moisture, air temperature, air humidity and light levels are all being addressed via the array of appropriate sensing devices that have been incorporated. These are employed to collect vital environmental data from different locations and then feed it back so that it can be examined. They furnish the operative with greatly enhanced visibility on how different environmental conditions are effecting the crop and enable well informed decisions to be made about what changes might need to be made to improve yields.

The root node collects sensor data that has been captured at the child nodes (1 and 2). It then transmits the data (concerning characteristics of the soil, air, etc.) to an Android application via a Wi-Fi module. The Android application (which can run on a wirelessly connected portable electronics platform, such as a tablet or laptop) is able to monitor all the information coming in simultaneously from that numerous connected sensors within the system. From ▷

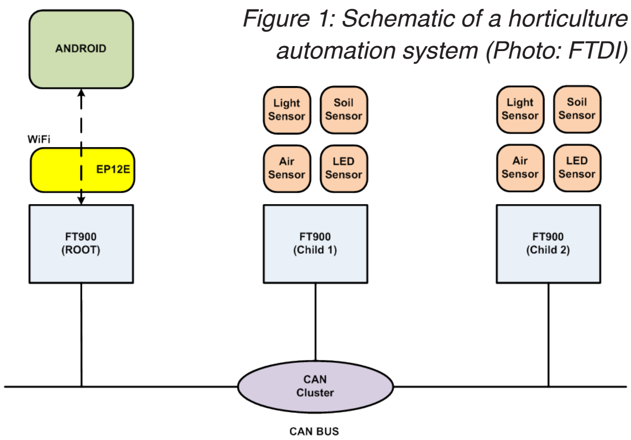


Figure 1: Schematic of a horticulture automation system (Photo: FTDI)

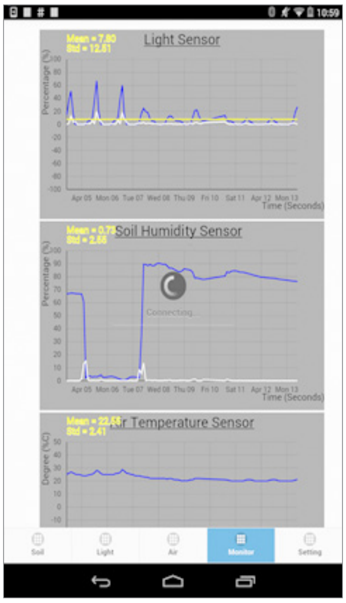


Figure 2: Android application displaying data captured and transmitted from one of the FT900 MCUs (Photo: FTDI)

this data it is able to generate a real- time 2D plot. In addition to the acquisition of uni-directional environmental data, bi-directional communication is used in regard to light conditions. An LED control panel can also be accessed. This provides the operative with detailed information on the light intensity and the light color that is being emitted from specific LED strings at that time. Through its adjustments to these parameters can be rapidly made when they are deemed necessary.

From a control perspective there is considerable scope to expand the functionality. It could be scaled up to include additional elements, such as automatically opening up greenhouse windows to regulate the temperature, or turning sprinklers on to increase humidity/soil moisture levels. Between 30 and 40 sensor nodes could potentially run on a single CAN network segment covering over a hectare of land.

The system described relies on three sets of FT900 Superbridge micro-controller units (MCUs), which are physically connected via a CAN cluster. These ICs each have a sophisticated 32-bit RISC-based processing core, which can run at speeds of 100 MHz and supply zero wait-state operation. This means they can support highly deterministic data transfer, with no latency issues to impact on the system's effectiveness. As a result these MCUs are highly suited to real-time data logging applications, such as the one detailed here. Alongside this, they possess a broad portfolio of connectivity options, such as CAN, Ethernet, USB, UART, SPI, and I²C interfaces. Cameras could be connected, too. ◄

Author

Gordon Lunn
Future Technology Devices International Limited (FTDI)
gordon.lunn@ftdichip.com
www.ftdichip.com

Assembly station with test equipment

The workstation used to assemble vehicle air-conditioning systems also tests the 40 LIN and CAN network connections.

Figure 1: At this workstation the employee assembles control units and panels for truck air-conditioning systems, and carries out tests for 100-percent functionality (Photo: MCD)

In production enterprises, assembly, and testing are often two completely separate processes. The resulting disadvantages are unnecessary displacements and a lack of feedback to the assembly workers. It is also unsatisfying for the workers to assemble a product without the certainty that it is functioning correctly. However, there is an alternative – as demonstrated by the fully integrated concept of a combined assembly and testing station in which panels and control units for truck air conditioning systems are fitted and tested at the same time. The station is built for use by one employee and can be easily integrated into any assembly line. This modern workstation solution is the brainchild of measurement and test engineering specialists at MCD Elektronik from Birkenfeld near Pforzheim, Germany. The enterprise mainly supplies test systems to the automotive industry throughout the world.

Good working climate

Vehicle air-conditioning systems generally consist of a control unit and the operating panel. Here the drivers use buttons and a rotary knob to set their "feel-good parameters" for the cab. The settings can be viewed on an LCD display. The control unit communicates with the panel via an LIN interface. Another LIN interface, two CAN interfaces, and several analog inputs provide the connections with the sensors and actuators.

There is one station each for the assembly of the operating panel and the control unit. Roller conveyors deliver all necessary components to be assembled. At one station the worker presses in the pin headers and displays of the operating panel using a manually operated press with integrated measuring function. At the second station the control equipment is assembled. Here the housing, the pre-assembled circuit board and housing cover are screwed into place. A pneumatic screwdriver is provided for this work step. The feeding device automatically transports the required screws to the screwdriver head.

Simply by turning around, the worker now faces the test cell. The test cell is equipped with workpiece holders both for the panels and the control units. Numerous tests are carried out on the panels. After placing them in the module tray they are supplied with current through their three connection pins and connected up to the LIN network. First the EEPROM of the panel with the customer-specific data is described and relayed to the control unit. The worker's instructions appear on the screen, and he activates the buttons and the rotary knob in succession. The test station analyzes the signals via the LIN network.

Then the module tray is closed and automatic tests are performed. Haptic tests include values for force, stroke, path and snap ratio. To perform these, an XY-table approaches the individual switches, which are activated

Figure 2: Placing a module in the test cell tray (Photo: MCD)

▷

Figure 3: In the foreground (right) the hand-operated press for panel assembly, (centre) the station for final assembly of the control unit, in the background the test cell for optical and electrical testing (Photo: MCD)

by a precision drive with motion controller. A mechanical probe simulates the human finger. The speed is selectable and the force path is recorded together with the current position. Data processing takes place directly in the motion controller. When the maximum force or a specific position is reached, the drive – and therefore the measuring process – stops. This is followed by the start of the measurement for the return path.

The interior of the test cell is darkened so that in a second test step the lighting of the switch and the display can be optically tested using a camera. First, all symbols are tested by the camera in incident light for completeness, position and angle. The automatic test system then checks all symbols in seeker lighting and functional lighting mode for intensity, RGB color, homogeneity, and illumination failures. The pattern of the LCD display is tested for short circuits, completeness and intensity.

Nothing gets past this testing station

Igor Gerdt guided the development of the assembly and test station. He explained: "We can identify errors and scratches on the symbols, illumination failures and wrongly placed LEDs. We also detect missing light conductors in the LEDs and missing segments in the LCD pattern." The operator is informed about the test results. NOK parts are ▷

Equipment of the assembly and test station

Components by MCD Elektronik:

- ULC rack with comprehensive measuring technology and bus interfaces
- Testmanager CE software and Cognex Vision Toolmonitor
- Electronic control and coordination of test procedures

Products of partner enterprises:

- Hand-operated press
- Screwing equipment with feed and sorting device
- Gravity-actuated roller conveyors
- Platform weighing machine for NOK parts
- Integrated label printer

Questions to Igor Gerdt

Q: When designing an interactive testing station, what criteria are important to you?

A: Ergonomic work, so that the operator feels comfortable in the working environment; short paths, to save time for test personnel; instructing the operator, safe retrieval of NOK parts; close coordination with the customer's needs and requirements; and last but not least space requirements as well as adjustment to the manufacturing/production conditions.

Q: Do you take cultural characteristics into account?

A: Depending on the location, there are specific cultural aspects that have to be taken into account, like the physical size of operating personnel, or specific language requirements in the user prompt.

Q: Do you have the possibility of gathering feedback from operators on the acceptance of your test stations? (or in plain English: how popular are your developments with employees?)

A: They are very well received and have been in use for years in our customers' production. This is ensured by close coordination and training. Initial training ensured a high degree of satisfaction.

Q: Model changeovers in the automotive sector are increasingly rapid. How easy is it to adapt a test station to new, changed components?

A: Our software and systems have a modular structure. This means that adaptations and refitting are fast, easy and uncomplicated.

Q: What contribution do MCD test stations make to increase productivity?

A: The rise in productivity is enormous; this is due to the combining and bundling of many individual work steps in an integrated overall concept. Thus the operator's activities are varied and productivity increases at the same time.

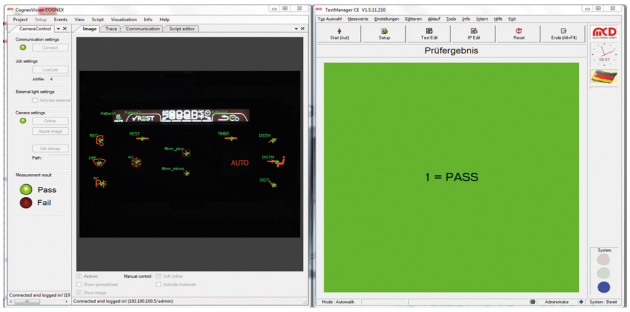


Figure 4: The green field shows the test cell operator that the DUT is one hundred percent in order (Photo: MCD)

set-aside safely by transferring them to platform scales situated next to the test cell.

In the testing of the control unit, the functions of the module are checked by activating and testing all signals. The 40 connections, including two CAN and two LIN connections, are automatically contacted after being placed in the testing station. The control unit reads simulated values for temperatures (air, water, cooling temperature), humidity and pressure via its analog inputs. The test apparatus stimulates the inputs with the corresponding analog voltages and frequencies.

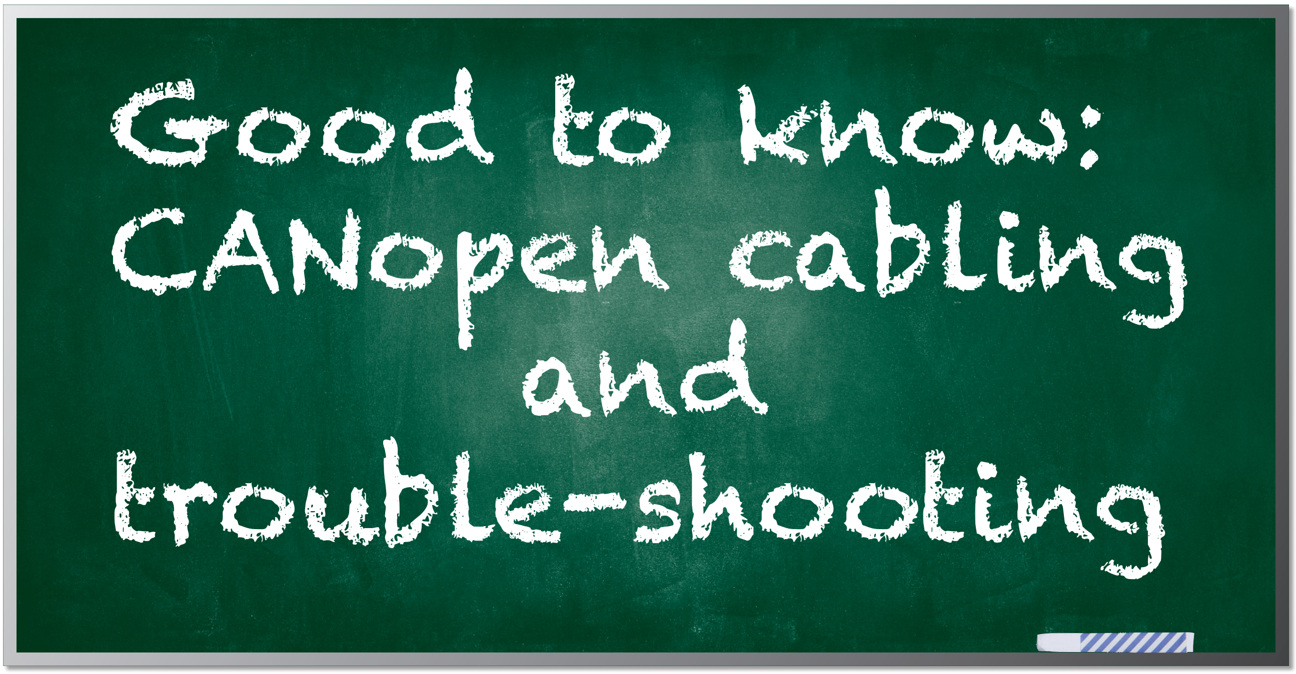
The control unit communicates via the CAN network with valves, the compressor, water pumps, and ventilation motors. The test cell program checks the correct functioning, and measures and evaluates the currents and the PWM (pulse-wide modulation). The feedback of the simulated air-conditioning components via LIN completes the test sequence.

If the test has been positive throughout, a label-printing device prints a corresponding label which is applied by a test cell operator and signifies that the tested components are "OK". The panel and the control unit are transferred by rolling conveyor from the assembly station to Production Logistics.

The assembly and testing process is supported by "stop – go" lights and monitor displays. Ingenious interlocking of the individual processing steps ensures that nothing is overlooked, and that the testing sequence is adhered to. ◀

Author

Joachim Tatje
Viatico Strategie und Text
tatje@viatico.de
www.viatico.de



This note provides some hints how to implement CAN networks regarding cabling, termination resistors, and other physical layer components.

Network problems are often caused by not using proper termination at both ends, wrong bit rates for cable lengths, incorrectly installed cables, and poor signal quality. Best practice is a bus-line topology with short stubs. The bus trunk line must be terminated at both ends by resistors that represent the characteristic impedance of the line. The not terminated stubs cause reflections and should be therefore as short as possible. In CiA 301 there are given some guidelines on the maximum single-stub length and the maximum accumulated overall stub-length.

Bus-line topology is ideal

CANopen is based on the CAN low-layers standardized in the ISO 11898 series. The bit-timing settings are recommended in CiA 301. Cabling and connector pin-assignments are recommended in CiA 303-1. CAN is a two-wire differential serial network. Actually, it is a 3-wire communication system, if you consider the ground line. Connecting the grounds between CANopen devices is highly recommended. Even when galvanic isolation is used, it is recommended to fin a path to ground.

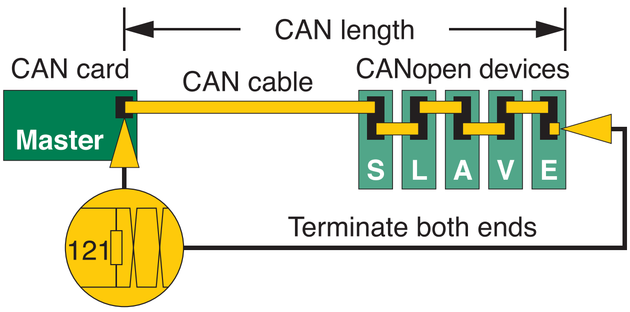


Figure 1: Typical CANopen network with Master at end of bus-line (Photo: CAN Newsletter)

In the past, most manufacturers did not ship CAN cards with termination resistors installed. Thus, for those CAN cards at the end of the bus-line, line termination must be installed. Nowadays, many of the CANopen products come with pre-installed termination resistor. System designers should disable them, if the device is not at one of the bus-line ends.

The maximum CAN length is 1 km at 50 kbit/s. The bus-line should be as close as possible to a straight line to keep reflections to a minimum. To extend the cable length (or to provide galvanic isolation) a bridge-device or repeater can be used. Figure 1 represents a typical network implementation. However, it is not the only one. It is also possible to have the master connected in the middle with no termination, with termination at the amplifiers at the end of the bus-line. If a cable stub (not terminated cable) or a T-connector is used to tap into the bus-line, then single-stub length should not exceed the values as given in Table 1. But this these values are for ideal conditions. For robustness reasons and to provide a safety margin, the value recommended should be much shorter. The CiA 301 CANopen specification provides recommended guidelines for maximum cable lengths at several bit-rates (Table 2).

Table 1: Maximum single and accumulated stub-lengthsbus-line (CAN Newsletter)

Bit-rate	Max. single stub length	Max. accumulated stub length
1 Mbit/s	1,5 m	7,5 m
800 kbit/s	2,5 m	12,5 m
800 kbit/s	5,5 m	27,5 m
250 kbit/s	11 m	55 m
125 kbit/s	22 m	110 m
50 kbit/s	55 m	275 m
20 kbit/s	137,5 m	687,5 m

Table 2: Not all CAN transceiver chips are able to support bit-rates lower than 40 kbit/s, some support just bit-rates up to 500 kbit/s (CAN Newsletter)

Bus-length	Bit-rate	Bit-time
25 m	1000 kbit/s	1 µs
50 m	800 kbit/s	1,25 µs
100 m	500 kbit/s	2 µs
250 m	250 kbit/s	4 µs
500 m	125 kbit/s	8 µs
1000 m	50 kbit/s	20 µs
2500 m	20 kbit/s	50 µs

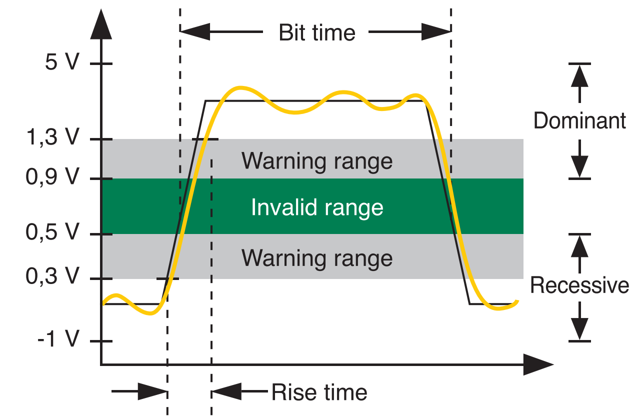


Figure 2: Recommended guidelines (Photo: CAN Newsletter)

Status LEDs are useful

The CAN LED as recommended in CiA 303-3 indicates the status of the CAN physical layer. Flashing red indicates errors due to missing CAN messages (Sync, Guard, or Heartbeat). Several manufacturers provide bus analyzer tools to help debug the CAN network. With power-off, you can use a simple Ohmmeter to verify 60 Ω between CAN_H and CAN_L. With the CAN network powered-on, you can use an oscilloscope to differentially measure the signal levels at both ends of the CAN network. Sending and receiving messages between the master and each slave node tests each device. Considering the thresholds given in Figure 2, you can measure if dominant or recessive signals are out of the invalid range and that rise times are lower than 15 % of the bit-time. ◀

Author

Cindy Weissmueller
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

Security architecture for CAN

Partly financed by European and Belgian governmental research projects, the Sancus approach is an ongoing initiative to develop a security solution for CAN-based embedded control systems.

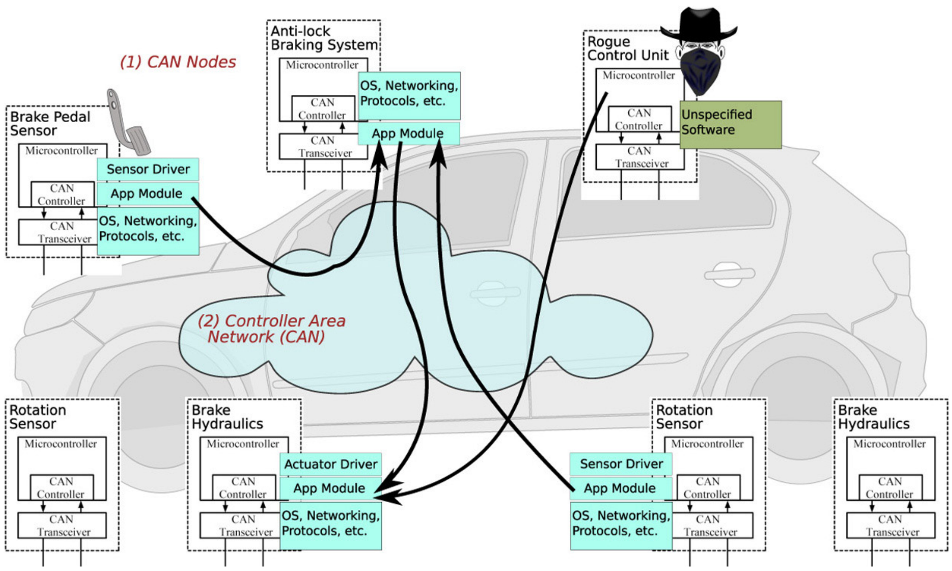


Figure 1: Networked control system with multiple ECUs and gateway with no protection against message injection or replay attacks (Photo: Imec)

Today, networked electronic control units (ECU) manage road vehicles. They interpret the sensor readings and operate the actuators to control the car's behavior and safety. They intervene for braking, steering, light switching, actuate airbags, and optimize the powertrain operation. The crux is: all these networks are connected and open to the outside world, which renders them vulnerable to malicious interferences. To establish an effective mitigation against such attacks, Imec has devised the Sancus security architecture for networked embedded devices.

Sancus has been designed and implemented by Imec's Distrinet and Cosic (both located at KU Leuven) – two research groups well known for their work on security matters. The development is supported partly by the Intel Lab's University Research Office. It was also partially funded by the Research Fund KU Leuven, by the European FP7 Project Nessos, and by the Belgian Cybercrime Centre of Excellence (B-CCentre).

Sancus was carefully laid out to fit the usual automotive electronics environments, and is intended as a general solution to secure not just vehicles, be they smart or autonomous, but also for other critical infrastructures, such as medical equipment, smart buildings, or power grids. To ensure that the results of the Sancus initiative can be verified and reproduced, the hardware design and software of our prototype have been made publicly available. Hardware designs, source files, as well as binary packages and documentations can be found at https://distrinet.cs.kuleuven.be/software/sancus.

CAN: island of smart electronics

Complex industrial equipment is monitored and steered by networks of sensors, actuators, and control processors that continuously exchange essential up-to-date messages. In automobiles, this real-time interaction usually is organized via CAN (Controller Area Network). The problem here is: CAN was laid out about 30 years ago as a closed network with no consideration of obvious access points for intruders. The CAN lower-layers offer a convenient way to integrate the growing number of heterogeneous sensors and control processors, which send and receive reliable and timely messages without any central computer. Most important: CAN networks connect the rotation sensors in the wheels with the anti-lock braking system (ABS) and the drivetrain.

Traffic infrastructure: opening up to the world

In high-end cars, the infotainment and navigation systems are hooked up to both, the CAN network and to external public networks. The infotainment equipment communicates via the driver's mobile phone or headset and they receive software updates from their vendors. With information provided by the CAN network, it is possible to turn up the music volume when driving faster or upon entering rough terrain. Autonomous vehicles take this a step further: they will communicate with the traffic infrastructure to steer and protect the car.

So, suddenly a car's CAN network provides a number of potential entry points for malicious intruders. Communication with the outside is done via Bluetooth or IP networks, some of which may connect to the Internet. And the Internet, if anything, is a highly non-trusted network. The CAN interface and it's hardware and software components were not designed to operate in such an unsafe environment. CAN ▷

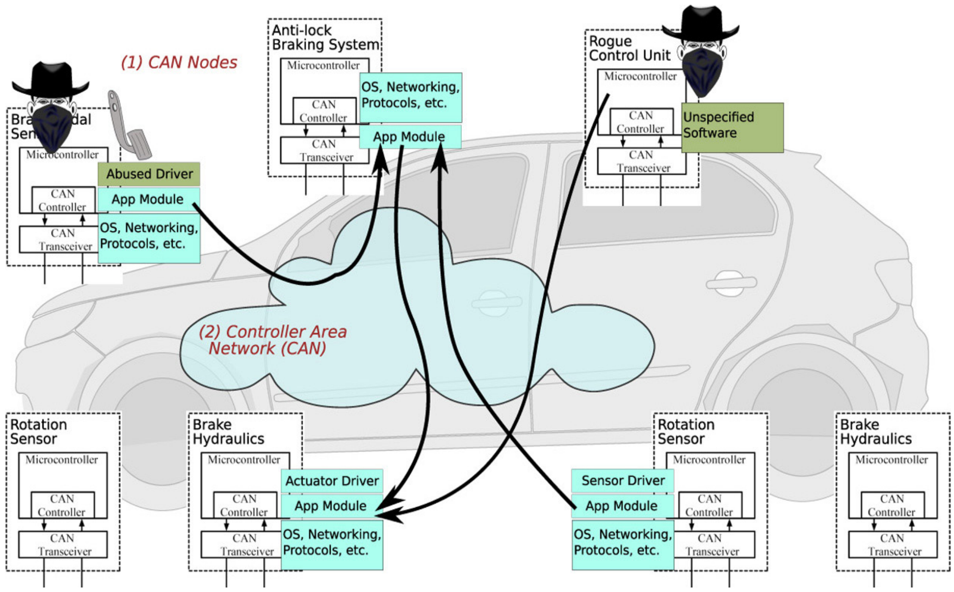


Figure 2: Classical CAN allows for two main attack scenarios. Firstly, in the absence of strong authentication mechanisms, a rogue ECU can inject message. Secondly, the lack of security mechanisms on many light-weight ECUs leverages software vulnerabilities as attack vectors. Even in the presence of authentication and encryption, attackers are able to control software directly, bypassing securing mechanisms (Photo: Imec)

offers no actual form of authentication or authorization. If a syntactically correct CAN message arrives at the car's brake system, it just assumes that the message is legitimate and stems from a trusted source.

Moreover, car network processors are designed to be very small and inexpensive, just good enough for their task, and consuming as little power as possible. They usually run tiny operating systems and some communication and control applications. They don't feature memory protection or an isolated sandbox to run processes in. Every application, also an application that shouldn't be there, is able to access and rewrite the complete processor memory.

All in all, this is a considerable risk and – an untenable situation. Reportedly, researchers were able to remotely control a car by hacking its Wifi or Bluetooth gateways. Also, in a high-stakes case in Ukraine, it was demonstrated that electricity grids could be taken over and manipulated by attackers. Imec's researchers were able to hack pacemakers, eavesdropping on the devices and injecting potentially harmful commands. ▷

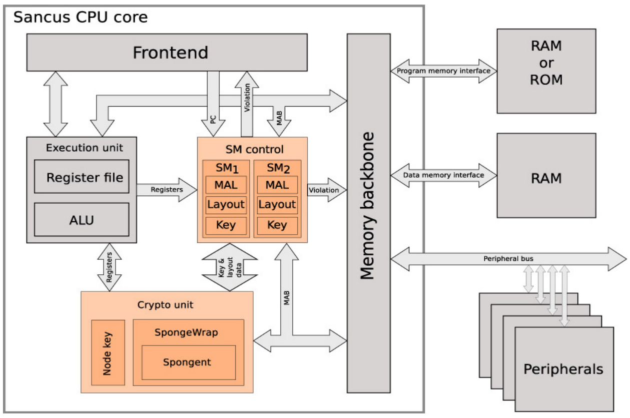


Figure 3: Block diagram of the Sancus CPU core (Photo: Imec)

This is not to say that such attacks are easy: They require a high level of sophistication, ingenuity, and patience. But in the case of highly sensitive road traffic environments, because of the sheer number of electronically identical cars involved, an attacker who manages to find a way into one system, poses a real threat to the security of a great number of other systems.

Establishing safe processing harbors

For all these incidents and scenarios there is no commercial mitigation available today. In contrast to higher-end processors in laptop computers and smartphones, the automotive control chips are small and resource-constrained. They lack the security features that are standard on other processors, such as various privilege levels and memory segmentations. Yet, replacing all embedded processors in cars with high-end systems is not an option, due to cost, complexity and power consumption.

Therefore, at Imec, we have initiated a research endeavor to design a new secure architecture that is suitable to secure today's embedded systems. It covers the CAN networks in cars, and also industrial control systems in manufacturing, or even very small IoT (Internet of Things) devices. Such security systems have to be low on complexity and cost – a definite requirement in regard to the envisioned applications.

We started out with a lightweight micro-controller and extended its design, adding a secure memory management and a crypto unit optimized for low-power consumption. The result is a processor that is not much larger and doesn't consume much more energy (about six percent). But it is able to isolate the critical network software and it creates a kind of a safe harbor for it. With this isolation concept, the software cannot be compromised. Its trusted computing base is restricted to the hardware on which it runs. Barring vulnerabilities in a protected application itself, no software, be it an application or operating system, running on the same processor or on an outside process, can override the security checks and read or overwrite the protected runtime state.

Knowing whom to trust

But even if the processor that controls the brakes of a car can no longer be hacked, it will still obey any brake command, even if issued by an illegitimate source. Therefore, we have limited the range of trusted message sources to those that can authenticate themselves as legitimate. Thus a brake command should only come from a trusted processor, which itself cannot be hacked, and from an authenticated software component. So the CAN network is now made up of small unbreakable applications that mutually authenticates and trusts each other.

In an automobile, such an embedded system must be able to be contacted from the outside, for instance by a software provider that wants to install updates, or, in a more general way, for communicating with the surrounding traffic infrastructure. Therefore, Sancus provides secure communication and remote attestation. Any outside party can send or receive messages to and from a specific software module on a specific node, while making sure that this is the correct module (authenticity), it has not been changed (integrity), and its status is correct (freshness).

Demo at ITF and future work

In May, we have demonstrated Sancus at our Technology Forum in Antwerp either in an automotive scenario and as a smart metering solution. Sancus is conceived as novel security architecture for resource-constrained, extensible embedded network systems. It provides remote attestation and ▷

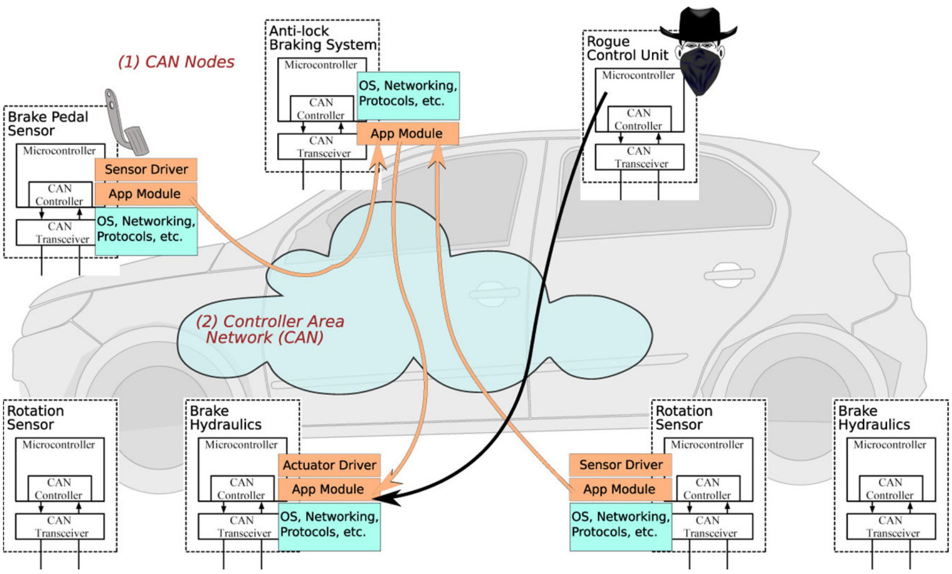


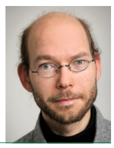
Figure 4: Legitimate nodes of the network run secure applications with Sancus' protection (orange), which matually authenticate each other and are protected against code-abuse attacks; rugue nodes cannot interfere with security (but may harm availability), node takeover is very diffecult, if not imposible (Photo: Imec)

Figure 5: Sancus prototype implementation (Source: Imec)

strong integrity, as well as authenticity guarantees within a minimal layout of a trusted computing base. Sancus consists of the specially extended microprocessor, the dedicated software running in the safe harbors, and a C compiler that generates the Sancus-secured code.

To be precise, Sancus still is an ongoing project, and the researchers need still resolve a number of issues to be included in Sancus. One of these issues is to ensure the availability and real-time function of the network. We can now guarantee that any messages that arrive in a module are legitimate. But we cannot yet ensure that they will arrive at their intended destination nodes. It would still be possible for an attacker to drop malicious messages – which our solution of course would detect. And in most cases this would probably not lead to dangerous situations, as the receiving node would raise an error flag and halt the system in a safe way. But this is of course inconvenient.

A second issue is safe operation of the secure software modules. Without formal design methodologies and inherently safe programming languages, these modules show vulnerabilities that may lead to unsafe operating situations. But due to the small isolated modules of trusted code, it should be possible to design these in a more formal, fault-free way. The researchers are still looking for collaboration partners to develop suitable hardware/software solutions. ◀



Author

Jan Tobias Muehlberg
Imec
jantobias.muehlberg@kuleuven.be
distrinet.cs.kuleuven.be/software/sancus

DC voltage debugging of an FPGA

This article introduces methods for optimally analyzing effects on an embedded system's power supply with an economy class oscilloscope. This includes the optimal horizontal and vertical settings.

A stable power supply is key to long-term operation of integrated circuits. Although this is especially true for high-end circuits based on field programmable gate arrays (FPGA), even lower-speed serial buses can significantly disturb a signal. A quick analysis using an economy class oscilloscope helps to improve system performance substantially. Using a few optimized settings of the oscilloscope can considerably improve the outcome of this analysis. The analysis, based on an exemplary DC supply voltage of an FPGA with a CAN interface, is performed using the RTB2000 oscilloscope by Rhode & Schwarz.

Optimized setting for DC voltage measurements

First, the DC voltage is analyzed without any special settings. Figure 1 shows the DC voltage measurement using a passive probe (10:1) connected to the DC voltage. In order to see the signal on the screen, the vertical scaling is set to 1 V/Div and a peak-to-peak voltage measurement including statistics is used to determine the ripple. The built-in voltmeter gives a measurement value for the DC voltage level of 4,92 V. In this setting, the mean value measured for the ripple is 179,90 mV (marked with the red circle with the built-in annotation tool for documentation).

Why does the vertical resolution of an oscilloscope play an important role? A quick initial estimation is the theoretical resolution of the oscilloscope in this setting. The RTB2000 uses a 10-bit A/D converter and therefore has 1024 decision levels. The vertical setting is 1 V/Div, yielding a full range of 10 V. Doing the math shows that the theoretical resolution is about 10 mV. And although the supply voltage looks flat, the mean ripple derived from over 10 000 measurements is 179,90 mV, or in the range of 3,5 % of the supply voltage. To improve the accuracy of the measurement, the channel offset is set to the 4,92-V level and the sensitivity to 20 mV/Div – which increases accuracy by a factor of 50.

As shown in Figure 2, the mean value of the peak-to-peak measurement is now 68,28 mV. This is about 2,5 times smaller compared with the initial measurement and is much more accurate, the 10-bit A/D converter resolution in this setting is approximately 0,2 mV.

Identification of disturbances of the DC supply voltage

The second step is to identify and correlate disturbances coupling into the DC voltage from other events. Looking at the signal change in Figure 2, it is hard to identify these disturbances, since the time base is not optimally chosen. A common approach is to capture longer time intervals to increase the chance to see coupled events, which are often based on slow signals. A typical source of coupled events for embedded systems comes from the AC/DC converter and may be related to the main supply frequency (50 Hz in Europe). In order to identify such patterns, the time base of the oscilloscope should be set to 10 ms/Div. In Figure 3, such a configuration is used together with an additional zoom window. In the upper trace, a pattern occurring approximately every 25 ms can be identified. In the lower trace, the signal is zoomed by a factor of 1000. We have used the built-in annotation tool of the ▷

Figure 1: Measurement of DC voltage without any optimized oscilloscope settings (Photo: R&S)

Figure 2: More accurate measurement results applying the right vertical settings and advanced frontend technology (Photo: R&S)

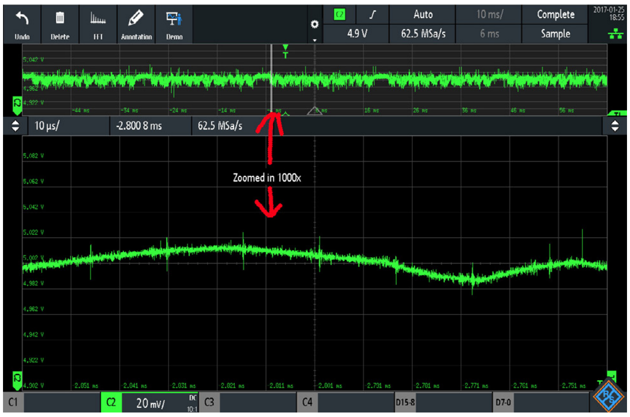


Figure 3: Low- and high-speed coupled events are captured using long memory (Photo: R&S)

Figure 4: Simultaneous display of analog DC voltage and CAN frame protocol as digital and decoded signal (Photo: R&S)

oscilloscope to indicate the additionally identified spikes, occurring approximately every 15 μs. We are therefore looking at two periodic events.

Both periodic events are visible in one screen because the 10 million samples per channel standard acquisition memory of the oscilloscope makes it possible to retain a high sampling rate. In this application, it means the complete acquisition time of 120 ms is captured with a sample rate of 62,5 million samples per second. In other words, events in the nanosecond range can be identified, allowing signals such as the fast periodic events to be reliably detected. In this article, our focus is on the larger, slower periodic event with the higher amplitude change in order to find the root cause.

The RTB2000 is a mixed signal oscilloscope (MSO) and optionally supports up to 16 digital input channels as well as serial triggering and decoding of CAN network signals. One of these digital channels is used to capture the CAN telegrams. This protocol is decoded using hardware acceleration and a color scheme to identify write/read addresses, data and all other bits of a CAN message. The screenshot in Figure 4 shows the digital channel as well as the decoding of the CAN telegram along with the DC supply voltage.

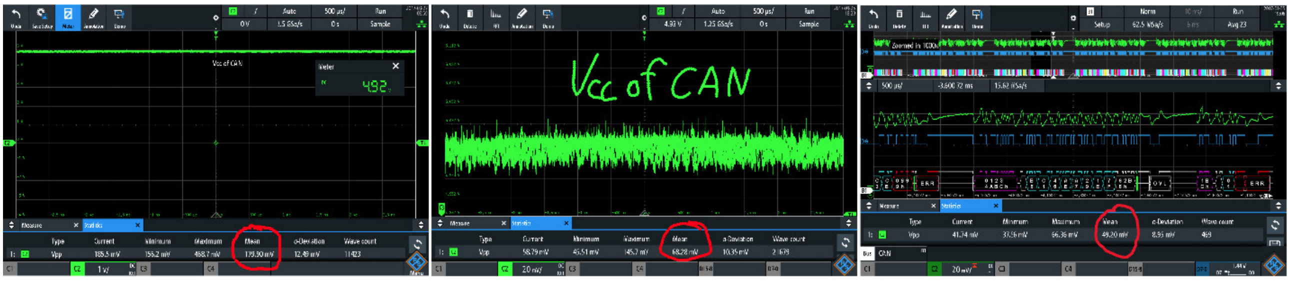


Figure 5: Side-by-side comparison of measurements (Photo: R&S)

The slow-speed repeating pattern on the DC voltage (25 ms) can be immediately linked to the CAN telegram. Whenever the FPGA starts to transmit CAN data, it loads the DC power supply and causes a ripple. Looking at the DC voltage change in the zoom window, the main ripple seems to be coming from bit switching, but there is noise overlaid, which makes it difficult to quantify the pure influence of bit switching. In this example, by triggering on a specific CAN address and/or data, and utilizing the DUT's (device under test) capability to send repeating CAN messages, we can find the ripple caused only by bit switching. The oscilloscope is set to trigger on a recurring CAN telegram and averages several acquisitions. The result is shown in Figure 6.

Averaging removes any noise not related to bit switching. Now the DC ripple caused by transmitting CAN signals is isolated and measured as 49,20 mV.

Comparison of measurements using different methods

In this article, using an economy class scope with 300-MHz bandwidth and 10-bit A/D converter, it has been demonstrated how the optimization of vertical and horizontal settings can provide detailed insight into the root causes of ripple on a DC power supply. Acquisition memory is also highly important, since most coupled events are by nature much slower in speed than the signals at the DUT. Moreover, the capability to trigger on specific serial data telegrams makes it possible to isolate root causes and perform precise ripple measurements. Figure 5 shows a side-by-side comparison of the three settings illustrating the measurement procedures.

Figure 6: Using averaging to remove the part of the DC voltage ripple not caused by bit switching (Photo: R&S)

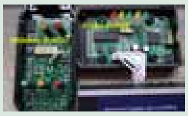
The initial measurement of the ripple of the DC power voltage was approximately 180 mV. Optimizing the vertical settings revealed that the ripple was only in the range of approximately 68 mV. Finally, the transmission of CAN data was identified as the main root cause of the ripple. This was only possible using long memory and capturing CAN network signals. By triggering on specific CAN data and averaging, the ripple on the DC power supply voltage caused by bit switching was measured to be approximately 49 mV, which is approximately 1 % of the nominal voltage.

Author

Andreas Grimm
Rohde & Schwarz
customersupport@rohde-schwarz.com
www.rohde-schwarz.com

CAN Newsletter Online: Most visited in 2017

The CAN Newsletter Online reports briefly about products and services.
This are the most visited articles in 2017 so far:

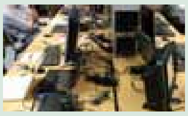


OBDII interface

Real or fake

It's a hobby: Taking on-board diagnostics information from the in-vehicle networks and observe and analyze them on a PC. Of course you want to pay as little as possible for the interface. That is why cheap, faked products are offered more and more often.

Read on

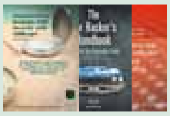


Clarification

ISO or non-ISO CAN FD

No doubt: in future all products will be compliant to the ISO standard (ISO 11898-1). But currently some components and tools still support the original CAN FD protocol, which is not compliant to the ISO standard.

Read on



CAN

List of available books with short descriptions

Since CAN's introduction in February 1986 by Robert Bosch more than 20 books about CAN and CAN-based higher-layer protocols (HLPs) were published. The following overview comprises all available books. They are written in different languages.

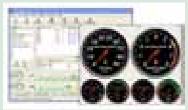
Read on

Night-blindness

ADAS fail to detect pedestrians at night

Emergency brake assistance systems claim to detect pedestrians and bicycles. The German ADAC automobilists' club has tested several cars providing such systems and found them lacking.

Read on



CAN networks

Open-source analyzer

Tiny-CAN View by MHS Elektronik is the open-source (only for Linux) CAN analyzer usable on Windows, Linux and Mac (in preparation) systems. The software is suited for long-lasting measuring. It is compatible to all company's Tiny-CAN products.

Read on

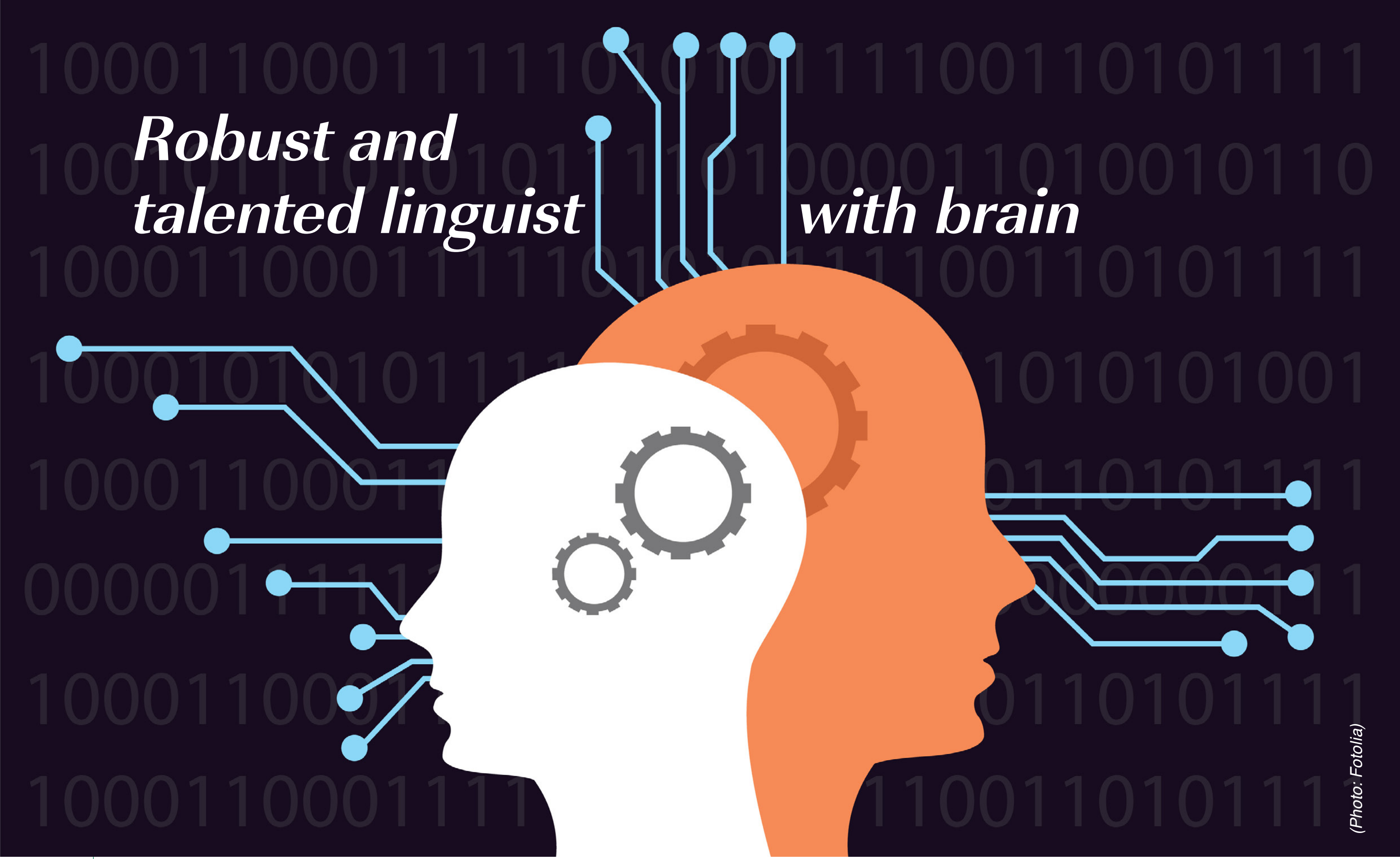
CAN FD demonstrator

With 20 nodes at a 40-m network

Texas Instruments (TI) has developed a CAN FD kit to demonstrate its 5-Mbit/s transceiver chips. The linear network topology features varying stubs with up to 2 m.

Read on

Robust and talented linguist with brain



(Photo: Fotolia)

The TBEN-L-PLC IP69K is a protocol converter that translates between CANopen or SAE J1939 and other serial communication protocols.

The automation sector is currently undergoing a major shakeup of old established practices. The change to digitally networked, highly flexible, and transparent industrial production, as described in recent years under the label Industry 4.0, is presenting designers and electrical planners with new tasks. One of the routines of mechanical engineering, and particularly in electrical planning, is the design of a control cabinet for protecting sensitive electrical and electronic equipment such as controllers, power supply units, or I/O solutions from the severe conditions present at the machine. With its robust portfolio of IP67/IP69K I/O solutions, Turck is also offering a smart alternative.

Potential of decentralized solutions

Decentralized I/O solutions in themselves are nothing new, but are becoming increasingly more important in the light of modern automation and machine concepts, which increasingly have a modular design. The trend is moving away from the control cabinet towards installation in the field. The use of robust I/O technology with protection to IP67 enables users to run the cables of the sensors directly in the field to a nearby I/O distributor, which can route the signals to the control cabinet, either as a passive multipole cable junction or actively as a fieldbus device. Compared to point-to-point wiring, this saves the user considerable costs for the connection technology and the wiring. There is also a time saving benefit when the machine is set up at the customer. Instead of running several individual cables to the control cabinet, it is normally only necessary with fieldbus or Ethernet systems to run one communication cable and power supply in order to connect the I/O level to the controller. The wiring of the periphery to the remote I/O technology can then be done in advance at the machine builder.

High performance

Turck takes the decentralization from the control cabinet to the field one step further. The TBEN-L-PLC Codesys-3 controller of the Muelheim automation specialist is a IP67 controller for use directly in the field. When used as a master, the device also supports Modbus RTU, in addition to CANopen and SAE J1939, as well as the industrial Ethernet protocols Profinet, EtherNet/IP, and Modbus TCP. The EIA-232 and EIA-485 serial interfaces can also be used as required in Codesys. The block I/O controller also offers eight universal I/O channels for the direct connection of sensors and actuators.

The TBEN-PLC can also be run as a slave (e.g. device) in the CANopen and Modbus RTU networks as well as in the three supported industrial Ethernet networks, ▷

Figure 1: The TBEN-L-PLC can form the bridge between Ethernet and CANopen with its various master and device interfaces (Photo: Turck)

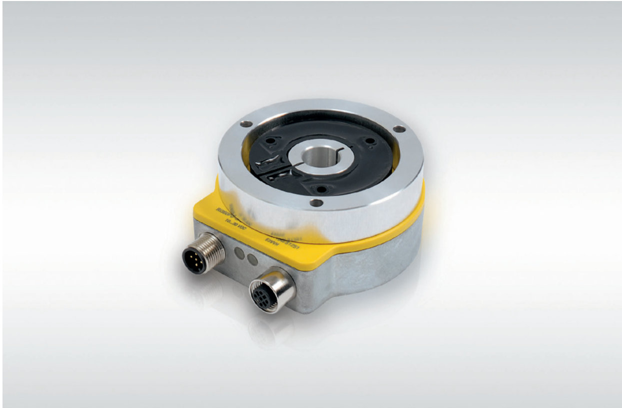


Figure 2: Turck offers inclination sensors, rotary encoders like the QR24 in this image, and angle sensors with a CAN interface (Photo: Turck)

thus enabling it to be used as a protocol converter. For example, the controller can operate as the CANopen manager of a machine module networked with CANopen and connect this module to a system running with Profinet. As part of the increasing digitization of industrial production processes, this enables existing machine concepts to be made fit for the challenges of closely networked, highly flexible production. Turck is thus providing an answer to the question of how existing machinery and plants can benefit from the increased efficiency and increased transparency as part of the evolution of Industry 4.0.

TBEN-L-PLC as protocol converter for CANopen

This is particularly of benefit to plant operators wishing to connect their plants and machinery to higher-level ERP or MES systems and therefore wish to network their machines to industrial Ethernet. Networking with Ethernet-capable components down to the lowest level of automation is not economically advisable necessarily and is rarely necessary in terms of automation. With the TBEN-L-PLC, existing valve blocks or drives which frequently talk in CANopen can also be used in industrial Ethernet ▷

Figure 3: In the mobile equipment sector, the PLC ensures optimum use (Photo: Fotolia)

networks. The compact PLC then functions in a Profinet network as a Profinet slave and translates this communication as a CANopen Manager for the CANopen devices in the CAN network.

As CANopen is widely used in the field of drive engineering and pneumatics, this protocol converter option is particularly useful here. In most cases the technical benefits of a completely new installation of drive engineering and pneumatics with industrial Ethernet interfaces mostly does not justify the costs involved in a comprehensive Ethernet network. Many of the components are not at all available with Ethernet interfaces.

Controller for mobile machinery

Besides the protocol converter function, the TBEN-L-PLC also allows stand-alone control of complete machines. These can be conventional machines or machine modules, as well as mobile machinery. Thanks to its fully encapsulated housing, the TBEN-L-PLC is particularly suitable for the field of mobile machinery. It is very well protected against vibrations and shock and thus complies with degree of protection IP65/67/69K. The extended temperature range from -40 °C to +70 °C and the fully screwed plug-in connections are important features in the field of mobile machinery. The fact that most programmers in the mobile equipment sector master Codesys makes it ideal for use in this sector.

As an increasing volume of data is being networked with Ethernet, the use of TBEN-L-PLC as a protocol converter can also be helpful here. Particularly when the user wishes to use peripheral devices with a CAN interface which have proved successful in the past or for which there is not yet a counterpart with an Ethernet interface.

The Turck sensors with a CAN interface are often used in the mobile sector. Turck thus offers its B1N (single axis) and B2N (twin-axis) inclination sensors with CAN here. Customers from a wide range of different sectors are purchasing the QR24 rotary encoder as well as the smaller QR14 angle sensor with a CAN interface. Both sensors are fully encapsulated and detect rotary movements without contact.

Besides the block modules of the piconet and BLcompact product families, the BL20 and BL67 modular I/O systems are also available with a CANopen gateway. For example, Turck's BL ident RFID system can also be connected to CANopen via BL20 or BL67 CAN gateways. ◀

Author

Markus Ingenerf
Turck
markus.ingenerf@turck.com
www.turck.com

CAN Newsletter Online: Highlights

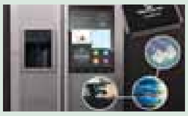
The CAN Newsletter Online reports briefly about products and services. In August, the following news were published:

CAN transceiver

With ±60-V fault protection

The MAX14883E transceiver is optimized for industrial applications. It features a ±60-V fault protection, a ±25-V functional common mode input range, and a ±10-kV ESD protection on the bus lines.

Read on



Micro-controller

Cortex-M4 processor with two CAN FD ports

Microchip has announced the SAM E5x micro-controller family. The 32-bit MCUs are intended for industrial applications.

Read on

Liquid Crystal Display

Integrated into headlights

Hella has developed LCD headlamps. In one approach, the pixel light distribution is calculated in an IC in the headlamp, which is connected optionally to CAN.

Read on

Safety PLC

Supports J1939, CANopen, and CANopen Safety

Ifm offers a SIL-2/PL-d-compliant host controller. The unit features four CAN interfaces.

Read on

Multi-function sensor

Turns vehicles into driving weather stations

Lufft has developed the Marwis weather-sensor detecting road and runway conditions. It comes optionally with CAN connectivity.

Read on

AUTOMOTIVE GRADE LINUX

Linux

Application service API for CAN

Automotive Grade Linux (AGL) has released the Unified Code Base (UCB) 4.0 platform. It supports CAN.

Read on

Remote attack

Security vulnerabilities on Tesla cars

Recently, Keen Security Lab discovered another security vulnerabilities on Tesla cars and realized an attack to CAN-connected ECUs with latest firmware.

Read on

Isobus

Autumn plugfest, pre-tests, and product releases

In anticipation of the Agritechnica 2017, Isobus services and products are increasingly launched. Additionally, the AEF organizes its autumn plugfest.

Read on

3D sensors: maneuvering instead of colliding

In all container ports worldwide reach stackers are used to stack and handle containers. To avoid collision within the container terminals during narrow and rapid maneuvering Ifm offers automatic collision avoidance.

The driver's eyes look straight ahead when moving the 14-m wide and up to 40-t containers attached to booms through the narrow container stacks. Even when maneuvering in reverse the driver must keep an eye on the transverse container to avoid hitting the containers stacked on top of each other like a wall. Again and again this brings up critical situations. For example when two reach stackers move towards each other while being maneuvered in reverse, when trucks cross the way, or objects or people are in the maneuvering range. With an ordinary rear view camera the driver can look behind but such a camera is passive, i.e. it does not warn in critical situations.

Ifm's O3M camera provides active protection: The integrated 3D sensor not only displays obstacles behind the vehicle on a screen in the cockpit but also determines the obstacle's size, position, and movement. Based on this detection of the environment and the reach stacker's own movement the O3M system assesses the critical relevance of objects. It warns the driver of the obstacles that are in the path or on a collision course. This prevents the driver from being irritated by too many warnings of objects in non-critical areas. Another advantage of the intelligent O3M system is that if another vehicle moves into the travel path from the side the risk is detected much faster than with a distance-based warning (Figure 1a, 1b).

The O3M system has two integrated cameras: A conventional 2D camera and a 3D camera that determines the exact distance to each pixel. The advantage for the user: Detected objects are highlighted in color in the produced 2D image. Critical obstacles can be highlighted, for example, in red, less critical objects in yellow or green (Figure 4). Furthermore, an additional warning symbol can be provided in this case. This overlay is completely generated in the O3M - so neither additional hardware nor complex set-up or programming is needed. Visualization can be easily and conveniently adapted to the application conditions with the ifm "Vision Assistant" software (color, symbols, language, etc.).

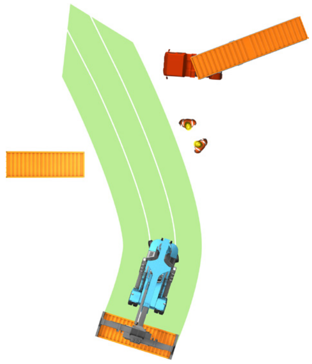


Figure 1a: Example for a non-critical situation in a curve (Photo: Ifm)

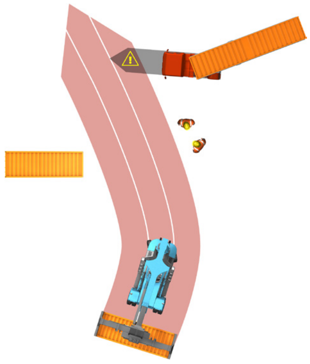


Figure 1b: Example for a critical situation because of a moving object (Photo: Ifm)

Parallel to the visual representation, a warning is transmitted to the CAN network which is used to produce an additional acoustic signal or even to intervene with braking. This reaction can be graded depending on the distance to the obstacle, i.e. at first an acoustic and visual warning is given. If the driver does not react and the situation becomes more critical, the vehicle can be braked gently (Figure 2a, 2b, 2c).

The integrated PMD 3D chip from Ifm detects scenes and objects three-dimensionally with only one image capture. This avoids the motion blur that can occur with line scanners. Ifm's patented PMD technology forms the basis for a sensor system that can cope with the harsh operating conditions of mobile machines. Besides the design the O3M sensor system is specially designed for outdoor applications with changing light conditions or bright sunlight. The 3D sensor has no moving components in contrast to other sensors such as laser scanners. Therefore it is particularly robust and not subject to wear. The operating principle of the PMD technology is based on the time-of-flight principle. The scene is illuminated by modulated, invisible infrared light and the reflected light hits the

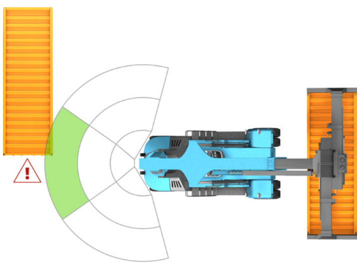


Figure 2a: Example for braking preparation (Photo: Ifm)

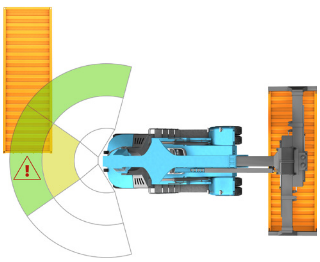


Figure 2b: Example for reducing speed (Photo: Ifm)

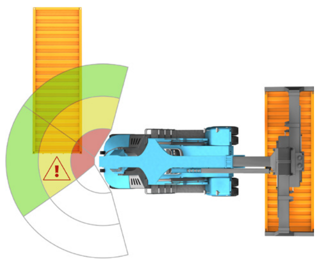


Figure 2c: Example for full braking (Photo: Ifm)

63 … 32	31	30	29 28	27 … 25	24	23 … 0
Byte 8 to Byte 5	r	a	b	c	r	Byte 3 to Byte 1
MSB						LSB

LEGEND
r = reserved
a = CP_minimum_zone_triggered (1_b = object very close to vehicle independent of vehicle movement)
b = CP_criticality (00_b = no crash predicted, 01_b = crash predicted with highest criticality, 10_b = medium criticality, 11_b = low criticality)
c = CP_crash_predicted (000_b = disabled crash predictor disabled, 001_b = temporarily not available, 010_b = crash predicted, 011_b = crash predicted, 100_b = error)

Figure 3: The 8-byte payload structure of the Crash-Predictor_Info message; in J1939 the extended CAN-ID 8382195 is used, in CANopen the PDO 4 with the default CAN-ID 896 is used, which can be configured to another value by the system designer (Photo: ifm)

PMD sensor. This sensor is also connected to the source of modulation. Each pixel of the PMD chip determines the distances to the scene due to the phase shift between the transmitted and the received signal. The integrated, active suppression of background illumination almost completely prevents saturation of the image sensor by extraneous light. That means that the PMD 3D sensor can be operated in bright sunlight up to 120 klx. The integrated 2 x 32-bit processor architecture ensures calculation of the 3D data directly in the system with up to 50 images per second.

The mobile 3D smart sensors feature some integrated evaluation functions which besides the collision avoidance described here, enable a multitude of other applications to be solved, e.g. line guidance or area monitoring. A highly developed algorithm from the automotive industry is used, ensuring automatic object recognition of up to 20 objects. In just a few steps the parameters of the system are set via the "ifm Vision Assistant" for Windows. To do so the user only needs to enter some parameters, e.g. regarding the vehicle's geometry. Usually this set-up only takes a couple of minutes and the system is then ready for operation.

One important goal for the usability of the O3M sensor is the integration into already existing infrastructure of the vehicle. This means that standard CAN protocols need to be supported and the 3D sensor output needs to be preprocessed in order to simplify and reduce the amount of information which needs to be transmitted to a standard controller. The functional output of the collision avoidance is available in a single, 64-bit CAN message. Basically, the output is reduced to the information if a collision is imminent and how critical the situation is. This CAN message is available using CANopen or J1939 (protocol and source address / node ID and can be set as parameters on the sensor). Some information on the message layout is shown in Figure 3. If needed, the complete 3D information can be processed via Ethernet UDP and an external process unit. This provides developers with an open system. ◀

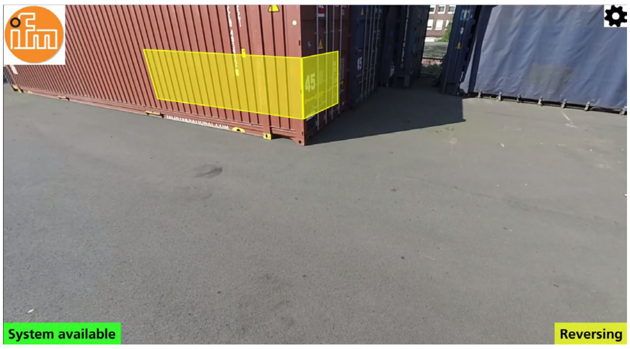


Figure 4: Critical objects are marked in the camera image (Photo: Ifm)

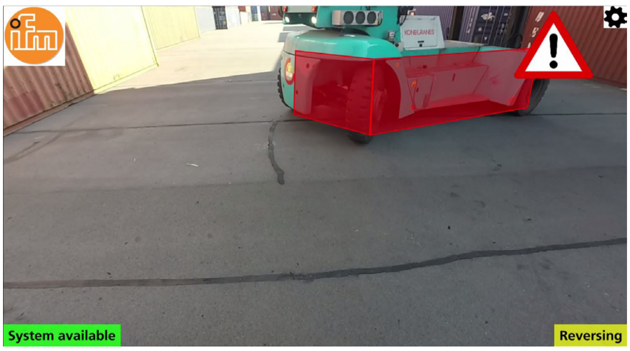
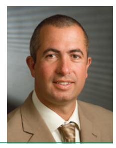


Figure 5: Camera image with a clear warning in the event of objects on a collision course (Photo: Ifm)

Author



Andreas Biniasch
Ifm Electronic
andreas.biniasch@ifm.com
www.ifm.com