September 2021

CAN Newsletter

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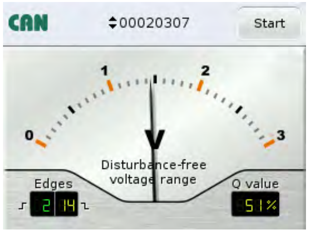

Engineering

Videos of 17th iCC papers plus iCC webinars

The 17th international CAN Conference (iCC) was the first online iCC held in June 2021. If you have missed it, do not worry: CiA offers to subscribe the recorded conference presentations as well as the conference accompanying webinars. For a small fee members and non-members can get access to these videos. The conference program and the webinar contents are available on the CiA website.

Selected iCC papers from previous conferences are available on CiA's Youtube channel. On this Youtube channel, you can also watch the preview videos of all papers and webinars of the 17th iCC for free. The iCC is a unique source on technical-in-depth information about Classical CAN, CAN FD, and CAN XL. The 17 conferences also provide many CANopen-related papers. Many of them are available for free-of-charge download on the CiA website.

Back in 1994, the 1st iCC took place in Mainz (Germany). The conference has established itself as a unique event, where CAN experts exchange knowledge and experiences. Usually, the conference proceedings are downloadable free of charge, when the next iCC is held. Since the 15th conference, the presentations are recorded.

CAN diagnostic for machine availability

Mobile machines are becoming ever more complex. A machine operating autonomously as much as possible is the objective of technical development work today. The data volume within such machines is continuously increasing, which also applies to the expectations regarding their availability.

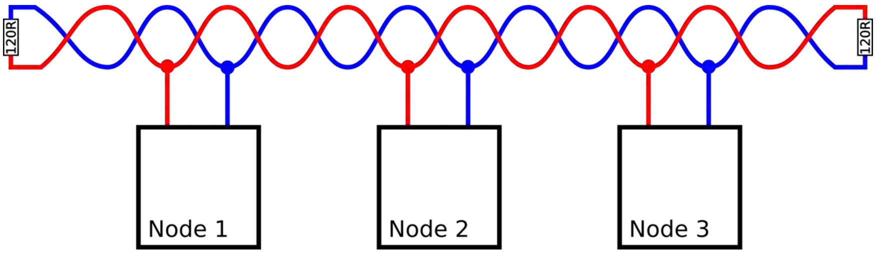

Figure 1: General design of a CAN network (Source: Gemac Chemnitz)

The backbone of data communication in most mobile machinery is the CAN network or an appropriate other serial bus system, such as SAE J1939, CANopen, Isobus, or NMEA 2000 based on it. A few of these machines are operated at their transmission borders; capacity utilizations of 80 % and more are meanwhile not seldom. This can lead to problems if external influences such as electromagnetic interference, trigger errors in transmission. Failures of the communication can be prevented by increasing the interference immunity.

In contrast to other bus systems, CAN already possesses an integrated error compensation in OSI layer 2 which automatically repeats messages in case of error. A so-called error frame indicates to the nodes in a certain segment that the last message was regarded invalid by at least one node. In this case, the CAN error management ensures that this message is discarded by all nodes and sent once more until the message has been understood by all nodes. The repetition of the messages has influence on the network load which can heavily increase since the messages are repeated quickly in succession in case of error. If the basic load is already very high, this can, in turn, have the consequence that messages with lower priority are no longer transmitted within the required time frame. This leads to uncertainties in the data situation, resulting in uncertainties about the machine status.

The error frame mechanism provides high data security for the CAN network, without extensive error handling in the upper OSI layers. Error frames are always a secure indication for the system operator that there are transmissions not performed successfully and that irregularities occurred.

Limiting the bus load

It must be an objective when designing and developing mobile machinery to keep the load in the central CAN system within a meaningful frame. Thus, sufficient time remains in case of error to repeat the message frames. Unfortunately, a lot of data is transmitted in many systems without first analyzing the effects for the bus load in detail. Data should only be transmitted if it is actually necessary to transmit them. For example, a temperature value could only be transmitted at a cycle of 10 seconds instead of every 100 ms and within this interval only when it drastically changes.

There are a few mechanisms that require more message frames for the monitoring of nodes than others. For example, the bus load can also be reduced by way of selection of the right mechanism. For example, the node monitoring log "Node guarding" in the CANopen system requires two messages whereas the node monitoring log "Heartbeat" requires only one message.

Other possibilities are the use of smart sensors and actuators. For example, only one command could be sent to a stepper motor once to traverse 1000 steps or 1000 single messages to traverse one step each time. Accordingly, when designing a system, each individual CAN frame should be checked for whether it is actually necessary. System planning is therefore performed moving from the level of the bus system (OSI 3-7) down to the CAN level (OSI layer 2).

Measuring the bus load

Measuring the bus load is simple and can be represented roughly by way of a CAN-to-USB interface. The bus load and the occurrence of error frames (where applicable), ▷

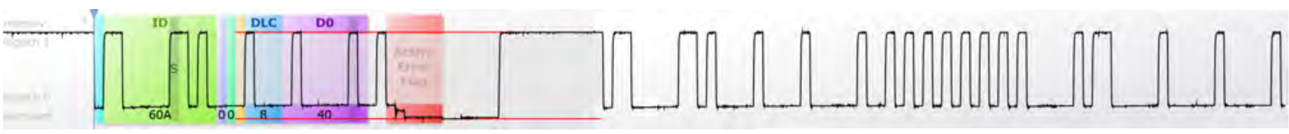

Figure 2: Active error flag with subsequent message repetition (Source: Gemac Chemnitz)

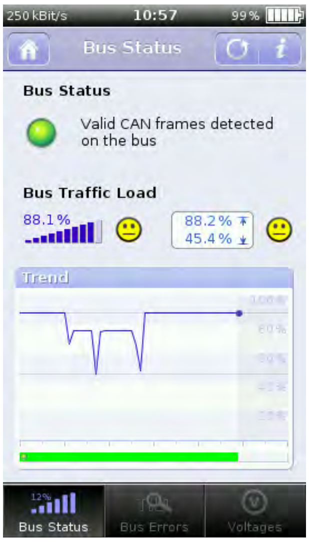

Figure 3: CANtouch measurement - Very high bus load (Source: Gemac Chemnitz)

for example, can be monitored without the necessity of using a PC thanks to appropriate hardware modules, such as CANalarm from Gemac.

The studies regarding OSI layer 2 should go one step further down to the level of physical bus characteristics (OSI layer 1). This is the level that indicates how interference-proof a CAN network is. If the data transmission cannot be disturbed by any external influence in the first place, error frames and telegram repetitions will not occur. Thus, the causes of the problem are addressed. It is also possible to increase the data rate if permitted by the topology. A pure line structure of the segments is ideal; stubs should be avoided where possible and be as short as possible. Usually, the data rate is doubled, resulting in halving the basic bus load. All nodes of a segment must be adjusted to the new bit-rate.

The reverse of the medal is: Doubling the frequency usually exacerbates the imperfections of the setup, causing the signal quality to drop. A possible remedy is only comparing measurements which can be performed both prior to and after a measure and thus allow to assess the measure. For example, the entire interference immunity can be improved significantly by selecting an appropriate cable. Both the signal quality and the interference immunity can be optimized by modifying the relevant factors step by step.

Factors that influence the signal quality

A CAN network is not only a cable with a switching signal. The transmission frequencies are high enough, already resulting in effects which can no longer be explained by way of direct voltage and direct current. As already mentioned, the signal quality is significantly influenced by the topology. Multi-tap ports are often used since they render the assembly easier. However, the nodes connected there are no longer arranged in the form of a line, but as a star. This results in reflections affecting the curve form of the signals. The same happens with stubs; therefore, the cumulative length of the stubs in a segment is to be kept small.

Figure 4: CANalarm (Source: Gemac Chemnitz)

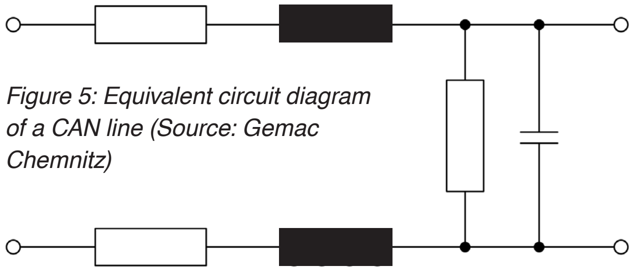

Figure 5: Equivalent circuit diagram of a CAN line (Source: Gemac Chemnitz)

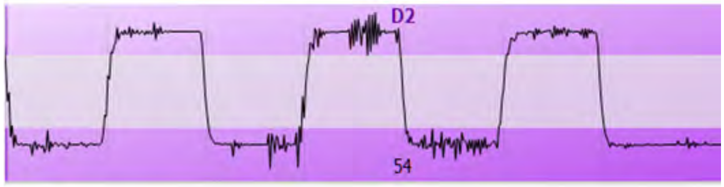

Figure 7: CAN differential signal with interference and reduced disturbance-free voltage range (Source: Gemac Chemnitz)

Furthermore, there are influences from capacitances and inductances introduced into the circuit by the cable and each node. The influence on the signal form increases with the bit-rate (and thus the frequency). This rounds the edges of the bits, influencing the signal quality.

Ideally, efforts are made to keep the contact resistances in the network system as low as possible. However, plug connections also produce additional resistances attenuating the signals. In practice, plug connectors with a contact resistance greater than 1 ohm have already been found which in total produced an additional resistance of more than 35 ohms in a short segment. Measuring the loop resistances could result in new insights. CAN differential signal with interference and reduced disturbance-free voltage range has the most decisive influence on the signal quality. Data transmission along CAN is performed by way of one differential signal. To transmit a logical 1, for example, the differential voltage between the CAN_L and CAN_H lines must be lower than 0,5 V. To be able to transmit a logical 0, this voltage must be at least 0,9 V.

Normally, a differential voltage of approx. 2,0 V to 2,4 V results at the CAN network when a logical 0 is transmitted. This voltage is reduced in case of interference. The safety reserve amounting to twice this voltage seems only to be large at the first glance. It can be reduced significantly if the interference is large enough. Interference sources are all electrical devices operating in the vicinity of the network, or also cables routed in parallel and whose electromagnetic signals are induced into the CAN line. External interference sources, such as other vehicles, high-voltage lines, cellular telephones etc. can induce their electromagnetic interference into the network. Depending on the circuit, the devices connected to CAN can also be sources of interference. A few CAN transceivers (the module that is connected directly to the CAN line) provide a differential voltage of approx. 1,8 V only due to a reduced supply voltage, which already worsens the initial situation.

The example diagram in Figure 7, shows that the aforementioned voltage reserve is already reduced by approx. 60 % (absolutely from 2,2 V to 1,45 V) as a result of an apparently small external interference. If the signal-to-noise ratio is too small, it can happen that bits are sampled incorrectly. This leads to an error in the checksum and is signaled by way of the error frame described above. As a result, the message is repeated.

Determined signal quality

The existing signal quality can be determined and monitored by way of appropriate measuring devices. Ideally, these devices produce a percentage value which can be compared directly. To be able to make a statement whether a certain value is good or bad, you will, however, still need further information in the form of a reference value.

A reference value can be obtained from a machine of the same type, for example. It would be better to possess a machine history of the current machine, which comprises all recorded measurement values, starting from a recorded final test after completed the manufacture of the machine, ranging to the measurement values determined at regular intervals within the framework of the service intervals. It is thus possible to assess the aging of the network, in addition to error diagnosis.

With its intensive fieldbus diagnostic, Gemac offers measuring devices which simplify the determination of relevant measurement data in such a way that statements regarding the signal quality and many further parameters are possible in a minimum of time and not to the disadvantage of the depth of information. The diagrams in Figure 8, show representations of two CAN signals, the signal-to-noise ratio, the edges in x/64 of the bit-time, the general quality value, and the representation of the curve form as an oscillogram with decoding. The smiley expresses an evaluation which can be captured at a glance.

Gain of information due to IFD

Comparing measurements of the physical bus play an important part in the development of a new machine. It can already be decided in this phase whether a different topology results in improved signal quality, for example, or whether any savings have negative effects. Purpose-oriented measurements performed both before and after such changes are an expedient method to find the best compromise between effort and benefit. The result of such a procedure are stabile CAN-based serial networks which also operate safely and reliably with increased bus loads. ▷

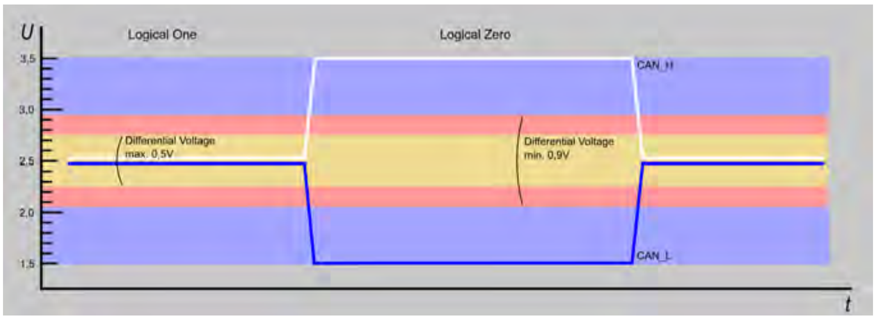

Figure 6: Formation of the CAN level of the differential signal (Source: Gemac Chemnitz)

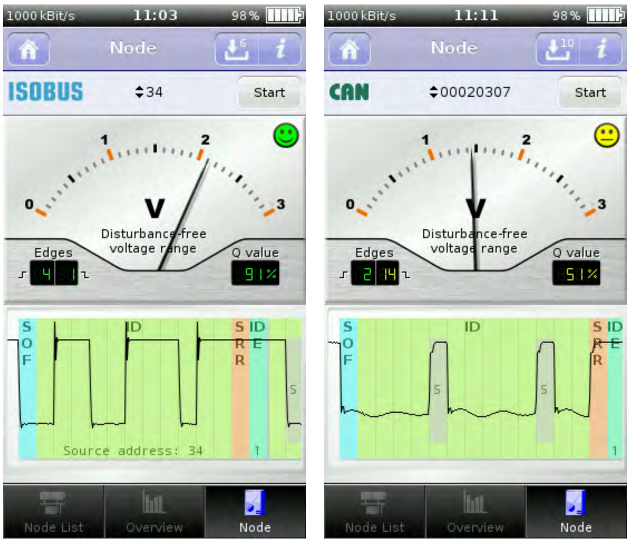

Figure 8: CANtouch: Quality value measurements on individual nodes (Source: Gemac Chemnitz)

In case of errors, it is now easier and more efficiently to perform systematic error localization with meaningful measurement values. Alone the statement that CAN is physically error-free can save hours of searching for errors. Regardless of the situation in which intensive fieldbus diagnostic (IFD) is used, due to the gain of information, users will always:

- Make data-based decisions;
- Design and produce machines which operate with higher stability;
- Minimize the downtimes;
- Accelerate the error localization and repair;
- Save costs.

Gemac Motus

With Gemac Motus, a configurable sensor measuring unit was designed for the most varied fields of application to perform 6-axis motion acquisition on mobile machines, such as construction vehicles, agricultural machines, forestry machinery, cranes and hoisting equipment, as well as vessels. Gemac Motus provides the decisive advantage that, in addition to the raw data for acceleration (in three axes) and speed of rotation (also in three axes), the internally calculated values, such as inclination or angle of rotation in different axes can also be output. This allows deviations to be recognized in the future still faster and more specifically. Now, thanks to combining and calculating the six measurement values, only one measuring system is to be integrated which covers the most varied requirements needs. The sensor comes with J1939 as well as CANopen interfaces complying with the CiA 301 application layer and communication profile and the CiA 410 CANopen device profile for inclinometers. The CiA 410 profile series specifies the application interface for single- and dual-axis inclinometers.

Figure 9: CANtouch (Source: Gemac Chemnitz)

The sensor-fusion algorithm

Figure 10: The inertial measurement unit Gemac Motus comes with J1939, CAN and CANopen interfaces (Source: Gemac Chemnitz)

The sensor-fusion algorithm specifically developed by Gemac provides precise orientation calculation supported by sensor fusion filters suppressing the externally acting accelerations. Complementary and Kalman filters were combined and expanded to be able to benefit from the advantages of the two methods and mutually compensate the disadvantages. It is thus possible to differentiate the determined (motion) status from external interference by way of the parameterizable algorithm. This provides a more practically-relevant measurement result.

All advantages of Motus at a glance:

- Increased measuring speed thanks to calculation already in the measuring unit;
- Improvement of the static and dynamic measurement accuracy;
- Space savings at the machine through saving of other sensors;
- Lower investment costs;
- Reduction of the costs for sensor technology;
- Reduced wear thanks to reduced number of components.

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Part 2: Comparing CAN, CAN FD, and Ethernet

This analysis compares Classical CAN, CAN FD, and Ethernet systems with focus on a decentralized battery management system. Part 1 of this article was published in the CAN Newsletter magazine issue 2-2021.

In Part 1 the test environment setup as well as the evaluation criteria for the comparative analysis were introduced. Part 2 provides related results and discussion.

Results and discussion

Frame processing time comparison: The frame processing times were first measured for different user data lengths of 0 byte, 8 byte, 64 byte, and 1 500 byte aligned with the maximum frame sizes of CAN, CAN FD, and Ethernet (Table 1). The frame processing time was measured using CAN with 500 kbit/s, CAN FD with 500 kbit/s, 1 Mbit/s, and 4 Mbit/s as well as Ethernet with 100 Mbit/s.

The highest frame processing duration for a user data transmission of 0 byte up to 8 byte is consistently CAN FD with 500 kbit/s. At the identical transmission rate as CAN, CAN FD is on an average 27 µs slower because of the longer control field (9 bit vs. 6 bit) in the CAN FD frames. The main advantage of CAN FD is the bit-rate switch (BRS), i.e. the increased data rate compared to the arbitration rate. This is not exploited in case of a constant transmission rate of 500 kbit/s, but at a transmission speed of 1 Mbit/s and higher, the transmission time is reduced and CAN FD reveals its advantage over Classical CAN.

Since only the transmission time of the data phase is reduced, the effect of the BRS increases with an increasing number of user data (Table 1). The increased data rate is used for the user data and the CRC (cyclic redundancy check) field. A further increase of the CAN FD data rate to 4 Mbit/s shows a considerable improvement of the frame processing time, which is especially effective with a high amount of transmitted data bytes.

Table 1: Measured frame processing times for various transmission rates and user data size (Source: OTH Regensburg)

	Message processing time in µs				
User data bytes	CAN (500 kbit/s)	CAN FD (500 kbit/s// 500 kbit/s)	CAN FD (1 Mbit/s// 1 Mbit/s)	CAN FD (1 Mbit/s// 4 Mbit/s)	Ethernet (100 Mbit/s)
0	99.2	126.2	91.3	69.5	44.3
1	114.5	140.7	99.3	71.2	43.8
2	133.1	158.5	108.7	73.5	43.7
4	163.4	190.9	125.2	78	44
8	227.6	257.4	158.4	86.7	44
16	-	389.5	222.6	103.9	44.1
32	-	657.2	355.8	139.4	46.8
64	-	1171.4	611.8	208.3	53.4
1500	-	-	-	-	314.7

The frame processing time of CAN FD is at any time significantly higher than the one of Ethernet. At 64 user data bytes, the time difference between CAN FD (4 Mbit/s) and Ethernet has increased to 155 µs. These differences become even more striking when the payload exceeds the frame size, i.e. multiple segments are necessary.

With a focus on the fastest possible data transmission, Ethernet is the communication technology of choice. Even with a payload of up to 64 byte, the data transmission is faster than with CAN FD. In addition, Ethernet enables user data transmission of up to 1 500 byte per data frame, which is higher than the maximum of 8 user data byte to be transmitted with CAN and the maximum of 64 user data byte with CAN FD (Figure 1). Comparing CAN FD and CAN, it becomes clear that CAN FD only shows advantages over CAN when bit-rate switching is used and the data rate is increased. Furthermore, it is shown that the effect of bit-rate switching becomes more significant as the payload increases.

When selecting the communication technology, the number of user data byte to be transmitted and the ratio between user data byte and overhead due to the data frame should be taken into account. If the objective is to transmit as much user data as possible within minimum time, the advantages of Ethernet outweigh those of CAN and CAN FD. For the transmission of fewer user data byte in short intervals, as it is the case for example within the DBMS (decentralized battery management system), CAN FD is definitely an option, especially if the transmission rate is further increased up to the maximum of 8 Mbit/s.

Processor workload analysis: The processor time is measured to compare the processor load caused by the respective communication technology. A part of the measurement is the required processor time for initialization. The initialization is executed once at system startup or after a reset. The initialization time for CAN (FD) is approx. 40 µs, whereas Ethernet requires 1,7 s and is over the factor 40 000 greater than the initialization time of CAN (FD) (Figure 1). Especially if an unexpected restart of the micro-controller and the applied real-time system occurs, the long downtime of the subscriber has consequences, including loss of information and the associated effects on system control and coordination. The Ethernet initialization time of 1,7 s (Figure 1) is quite long compared to the one for CAN (FD). The reason for this is the built-in Ethernet PHY (physical layer) on the applied evaluation board. By replacing the Ethernet PHY, the Ethernet initialization time could lie within the millisecond range.

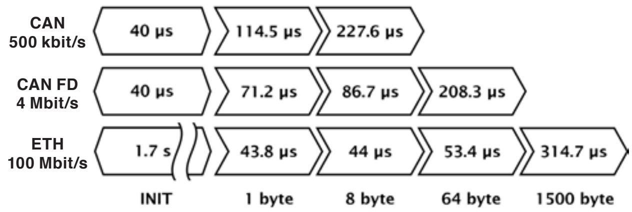


Figure 1: Initialization and frame processing time for varying user data size (Source: OTH Regensburg)

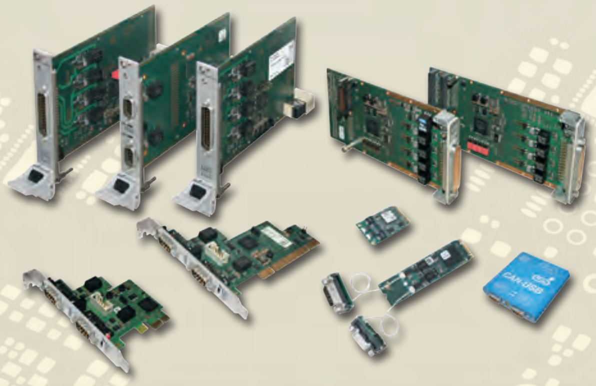
Next, the processor load for CAN (FD) communication for sending and subsequent receiving of 1 000 data frames is measured. Varying numbers of frames showed a linear behavior between the CAN FD process and the number of frames. The processor time of the CAN FD process increases with the number of frames.

The processor times were measured for intervals of 0,2 ms, 0,3 ms, 1 ms, and 10 ms. For shorter intervals between frames, the processor time share for the CAN FD thread increases slightly. With the shortest frame interval of 0,2 ms, the share of the CAN FD thread process is still only 1,5 %. The measurements show that the CAN FD communication only places a low overall load on the processor and cannot overload the processor due to communication channel restrictions limiting the transmission speed beforehand.

Measurements for CAN communication showed that it requires 10 µs less processor time for 1 000 data frames compared to CAN FD communication. Examining the percentage processor utilization, there are no differences compared to CAN FD communication. Therefore, only the CAN FD measurements are used for the comparison with Ethernet. Receiving and unpacking CAN (FD) data frames is handled by an interrupt service routine and depends on the length of the user data. For example, for 8 byte of user data it takes 3,3 µs whereas it takes 7,8 µs for 64 byte (Figure 5).

The measurement of the processor times for sending of Ethernet frames shows that the processor times do not behave linearly, especially for a few frames, in contrast to the processor times for CAN (FD). The reason for this are threads, which are executed in a fixed time interval independent of the number of frames. The shorter the frame interval, the more processor time is required by the Ethernet threads. With a send interval of 10 ms the Ethernet communication requires only 1,8 % of the processor time while with a send interval of 0,2 ms it already requires 23,8 % of the processor time. If the increase is linear to the send intervals, it is possible that the processor utilization limit occurs before the minimum send interval limit of Ethernet, which is 5 µs. This behavior was not investigated in this work because such a short send interval is not necessary for the DBMS.

The measurements show that Ethernet communication requires significantly more processor time than CAN (FD) communication. At a transmission interval of 0,2 ms, Ethernet requires 23,8 %, while CAN (FD) requires only 1,5 %. The processor times are additionally strongly dependent on the transmission intervals. The processor load therefore depends on the communication technology and additionally on the selected frame interval. For the selected minimum frame interval, neither Ethernet nor CAN (FD) communication significantly loads the processor. ▷



For receiving and unpacking of Ethernet frames, a separate thread and an interrupt service routine is used. For 8 byte of user data it takes 18 µs, which is significantly longer compared to the duration of 3,3 µs for CAN (FD) frames. With the maximum of 1 500 byte of user data, receiving and unpacking the frame takes 83,9 µs.

Energy consumption comparison: Since the same peripheral units are used for CAN and CAN FD communication, the energy consumption is combined for both types of communication. The processor operates constantly with a frequency of 400 MHz and an operating core voltage of 1,2 V. The operating voltage of the peripherals is 3,3 V. The total energy consumption is calculated in each case, including the necessary peripheral units, system components, and the supply of external peripherals. For Ethernet communication, significantly more peripheral units and system components are required and additionally the cache is utilized.

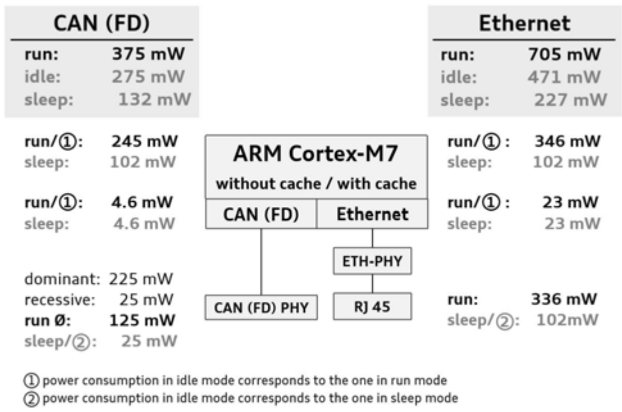


Figure 2: Energy consumption of CAN (FD) and Ethernet for diverse peripheral units in run, sleep and idle mode [5], [9]–[12] (Source: OTH Regensburg)

The energy consumption is calculated in run, idle, and sleep mode (Figure 2 and Figure 3). CAN (FD) communication requires significantly less power than Ethernet communication in all three modes. In run mode, the power required for CAN (FD) of 375 mW is just 53,2 % of the power required for Ethernet. Similarly, in sleep and idle mode, the power required for CAN (FD) is only about 58 % of the power required for Ethernet. For Ethernet and CAN (FD) the sleep mode is significantly more efficient than the idle mode. Only 48 % of the power required for idle mode is consumed in sleep mode.

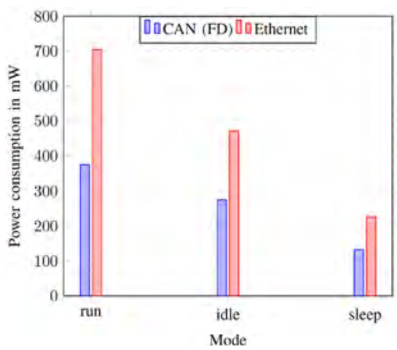


Figure 3: Power consumption comparison [5], [9]–[12] (Source: OTH Regensburg)

For energyefficient applica-tions, CAN (FD) communication shows clear advantages with almost 50 % lower power consumption than Ethernet. For all three communication technologies, using sleep mode instead of idle mode shows a significant improvement in energy efficiency. If Ethernet is required due to its significantly higher transmission rate, the sleep mode should be considered with regard to energy efficiency.

Error rates: The error rates provide information about the reliability and the correctness of data transmission. The RER (residual error rate) of CAN (FD) communication is officially specified as 4,7 · 10^{-11} [13], [14], whereas no official data is available for 100BaseT Ethernet. Direct code analysis (DCA) is used to determine the RER, which depends mainly on the polynomial of the CRC, the BER (bit error rate), and the frame length [15], [16]. DCA generates all possible error patterns, resulting in a sharp increase in computational effort with data length. Figure 4 shows the upper and lower limits of the RER for CAN with an 8-byte data frame and a 15-bit CRC as well as for Ethernet with a 42-byte data frame and a 23-bit CRC [15].

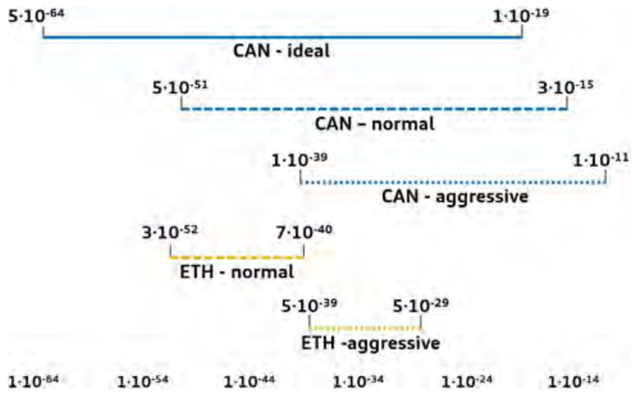


Figure 4: Upper and lower limits for RER of CAN [17] and Ethernet [16] in different environments determined by using DCA [15] (Source: OTH Regensburg)

To determine the BER, a large number of frames are sent under different conditions and the number of bit-erroneous frames is obtained. Table 2 shows the BER for CAN at eight user data byte [17] and for Ethernet at 1 468 byte of user data [16].

Table 2: BER of CAN and Ethernet for different environments [16] (Source: OTH Regensburg)

Environment	BER of CAN	BER of Ethernet
Ideal	$3.0 \cdot 10^{-11}$	-
Normal	$3.1 \cdot 10^{-9}$	$3.35 \cdot 10^{-10}$
Aggressive	$2.6 \cdot 10^{-7}$	$3.0 \cdot 10^{-8}$

Ethernet has a calculated maximum RER of 7 · 10^{-40} while CAN has a RER of up to 3 · 10^{-15}. Ethernet shows clear advantages in the RER, which has a greater impact due to non-detection, compared to the BER. All RER values are significantly below the limit value of 10^{-7} defined in ISO 61508 and ISO 26262, which has to be observed for communication technologies in critical applications. The BER of Ethernet is also smaller than that of CAN by a factor of about 10. Ethernet therefore shows an advantage with regard to the error rate.

Rx-Fifo load: To test the Rx-Fifo load, random frames were generated. For CAN, CAN FD, and Ethernet no noticeable Rx-Fifo load occurs. Table 3 shows the frame processing time, which includes frame generation, transmission, and unpacking of the frames, compared to the pure frame receiving and unpacking time. When ▷

comparing these times and taking into account that all communication participants share a common communication bus, it is evident that no significant Rx-Fifo load occurs (Figure 5).

Table 3: Comparison of the frame processing time and the frame unpacking time (Source: OTH Regensburg)

	CAN	CAN FD	Ethernet
Transmission rate:	500 kbit/s	4 Mbit/s	100 Mbit/s
Send interval:	300 µs	200 µs	120 µs
User data:	8 byte	64 byte	1500 byte
Message processing time:	227.6 µs	208.3 µs	314.7 µs
Message receiving and unpacking time:	3.3 µs	7.8 µs	83.9 µs

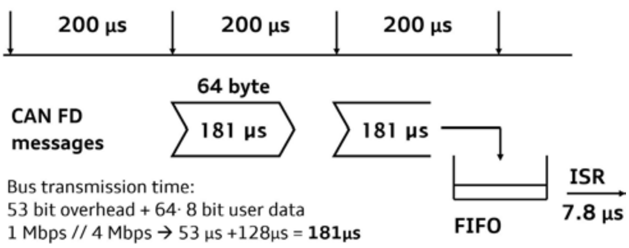


Figure 5: Comparison of the transmission time and the receiving and unpacking time of CAN FD frames with 64 user byte at an interval of 200 µs. The arbitration bit-rate is 1 Mbit/s and the data transmission rate is 4 Mbit/s (Source: OTH Regensburg)

The Rx-Fifo utilization increases with the frame receiving and unpacking time. CAN is particularly advantageous here with a receiving and unpacking time of 3,3 µs for the maximum 8 byte of user data. Ethernet takes 83,9 µs for receiving and unpacking 1 500 byte of user data, which is significantly longer in comparison to CAN (FD). The ratio of the unpacking time to the frame processing time of 314,7 µs and the minimum possible transmission interval of 121 µs, still indicates that the Rx-Fifo is not significantly loaded.

Conclusion

The application of the communication technologies Classical CAN, CAN FD, and Ethernet in networked control systems and especially in the DBMS was evaluated on the basis of the criteria frame processing time, processor load, power consumption, error rate, and Rx-Fifo load. In terms of frame processing time, Ethernet showed significant advantages due to its high transmission rate of 100 Mbit/s (Table 4). When transmitting 8 byte of user data, Ethernet is approximately 80 % faster than CAN and 50 % faster than CAN FD. CAN FD already shows clear benefits over Classical CAN. For transmission of 8 byte of user data, CAN FD with a data rate of 4 Mbit/s is 60 % faster than CAN.

None of the investigated communication technologies noticeably loads the processor. With a transmission interval of 200 µs, CAN (FD) communication requires only 1,5 % of the processor load, while Ethernet requires 24 %. For energy-efficient applications, CAN (FD) is preferred as it consumes 50 % less power than Ethernet. In terms of ▷

Table 4: Comparative analysis of CAN, CAN FD, and Ethernet (Source: OTH Regensburg)

	CAN	CAN FD	Ethernet
Payload data	low	low - medium	high
Message processing time	+	++	+++
Processor workload	+++	+++	+
Energy consumption	+++	+++	+
Error rate	++	++	+++
Rx-FIFO load	+++	+++	++

error probability, Ethernet offers advantages with at least a 10-fold lower error occurrence, whereas all communication technologies are suitable for safety-critical systems due to their low error probability. CAN, CAN FD, and Ethernet did not show any noticeable load on the Rx-Fifo due to the short receive and unpacking times in relation to transmission times.

Ethernet offers excellent characteristics in the transmission of large data amounts and in the error rate, but it requires significantly more power and processor time. The long initialization time of Ethernet is critical for real-time systems and networked control systems. For these applications, an Ethernet implementation without lwIP has to be considered. CAN FD has significant benefits in terms of frame processing time, even with few user data, and requires the same amount of power and processor time as CAN. In addition, CAN FD offers the possibility to transmit up to 64 user data byte and to increase the data rate even further. For these reasons, CAN FD is evaluated as the most appropriate communication technology for the DBMS. For applications with a higher number of user data byte, Ethernet is suitable.

Outlook

In further comparative analyses, CAN XL [20], Energy Efficient Ethernet (EEE) [22], and Ethernet Time Sensitive Networking (TSN) will be considered. CAN XL, with a maximum user data transfer of 2 048 byte and data transfer rates of up to 10 Mbit/s, is the successor to CAN FD. With the higher data rates and number of user data, the gap between CAN and Ethernet is steadily closing. EEE is an extension of Ethernet with the aim of reducing power requirements. Ethernet TSN is a standard extension of the IEEE with the aim of achieving real-time capability of Ethernet. Among other things, real-time capability is enhanced by time synchronization, prioritization, scheduling, traffic shaping, and resource reservation [23] and is promising for networked control systems. ◀

This article is split in two parts. If you have missed it, in the June issue of the CAN Newsletter magazine you can read Part 1. This article was originally presented as a paper at the Embedded World Conference 2021 Digital.

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The brain of the machine

The logistics industry is booming. With growing demand, there is need for transport solutions, especially within the warehouses. BHS Intralogistics has developed an autonomous transport shuttle. The brain of the shuttle is STW's CANopen-capable ESX.4cs-gw control unit.

Figure 1: The individually-scalable transport platform iShuttle (Source: BHS Intralogistics)

Hardly any other industry has experienced the years of upswing than the logistics branch does currently. In 2020, the coronavirus pandemic (Covid-19) and the associated increase in demand in e-commerce meant positive results throughout the branch. However, continued growth is leading to a shortage of skilled workers within the industry and an increasing need for automation, especially in intralogistics. More and more frequently, autonomous tugger trains and automated high-bay warehouses are taking over tasks that were still being performed by skilled workers just a few years ago. This trend is enabled by increasing digitalization of the infrastructure within warehouses, and increasingly powerful control and sensing technology in autonomous vehicles and machines used in the internal material flow.

An individually scalable transport platform

BHS Intralogistics is a joint venture, founded at the end of 2018 between the machine and plant manufacturer BHS Corrugated and automation and control specialist KS Control, which has specialized in the development of machines and systems for automated processes in internal material flow and load tracking.

One of these machines is the iShuttle, an autonomous mobile transport platform with a load capacity of up to 4,5 t. The shuttle is only 285 mm high and can be integrated into the in-plant transport flow, independent of the spatial conditions, with 2D laser navigation or camera supported line guidance. Multiple iShuttles of different sizes can be integrated as a fleet solution with the autonomous shuttles customizable to the customer's requirements. With different platform configurations such as lift table, push and pull function for goods transfer, belt or chain conveyor, and variable travel speeds, the iShuttle is suitable for a wide range of intralogistics tasks.

Safety first

Control systems from STW play a significant role in the safe operation of the autonomous transport platforms. The automation specialists have been supplying control components for mobile machinery for over 35 years, from agricultural technology and construction machinery to material handling machines, as in this case. When BHS Intralogistics was looking for a control system manufacturer that could offer proven functionally safe controllers for their industry, the choice quickly fell on the CANopen-capable ESX controller family from this long-established company from Kaufbeuren, Germany.

„With the development of our iShuttle, we did something very new. It represents the first autonomous driverless transport system in our portfolio, and we were looking for control expertise with plenty of experience, especially regarding the functionally safe design of mobile machines. STW is exceptionally well established in this field," explained Tristan Warias, software developer at BHS Intralogistics.

Six CAN interfaces

In the iShuttle, an ESX.4cs-gw operates as the managing controller. The ESX.4cs-gw has a three-core processor (an Infineon Aurix, 3 x 300 MHz), six CAN interfaces, and five Ethernet interfaces. With the help of a managed ▷

Figure 2: The transport system in action (Source: BHS Intralogistics)

four-way 100 Mbit/s Ethernet switch, large amounts of data can be selectively forwarded in the system without using processor power. "With our new generation of controllers, machine manufacturers have even more performance at their disposal. The powerful processor and extensive support for sensor integration contribute to this," said Stefan Hohn, STW project manager, in explaining the advantages of the ESX.4cs-gw. To avoid any safety risk, the ESX controllers regulate the iShuttle's drives in accordance with safety integrity level 2 (SIL) and performance level d (PL d). This was the functional safety requirement for the iShuttle to be able to operate in an industrial environment. In the iShuttle, two additional ESX.3ios controllers are connected to the managing controller via CAN, expanding the functionality and connectivity options, for example for the autonomous vehicle's extensive sensor suite. Thus, in this application, the ESX.4cs-gw is found in its ideal role as a central node that can receive, process, and distribute a large number of CAN signals.

In general, all six CAN interfaces of the ESX.4cs-gw are CANopen-capable. The communication interfaces comply with the CANopen application layer and communication profile CiA 301. This includes the data types, encoding rules, and object dictionary objects as well as the CANopen communication services and protocols. In addition, this specification defines the CANopen network management services and protocols. It also defines the CANopen communication profile, e.g. the physical layer, the predefined communication object identifier connection set, and the content of the Emergency, Timestamp, and Sync communication objects.

For safety-relevant communication, the controller supports CANopen Safety and the CAN Safety protocol ECeS developed by STW. STW's SIL2/PL d-certified protocol significantly reduces the amount of data required on the CAN network, and so the bus load is significantly lower than that of the generic CANopen Safety protocol thanks to the reduced amount of data.

The ESX.4cs-gw from STW supports bit-rates of up to 1 Mbit/s. A reliable connection to the machine is guaranteed via an 80-pin Molex CMC connector in a 48/32-pin configuration. A wake-up functionality can be realized on CAN 1. CAN 4 can be implemented as a galvanically-isolated interface to isolate supplementary functions from core vehicle or application functions and prevent any potential interference.

Finally, two of the CAN lines can be daisy-chained with CAN-In and CAN-Out connectors. For machine manufacturers this means simpler implementation of CAN chains and a reduced cable harness.

Application-specific programming

Users of the ESX.4cs-gw have various options for the development of the application software at their disposal: The free open-source development and life cycle management tool Opensyde from STW offers the possibility to map and test functionalities in "C" as well as according to IEC61131 (logi.CAD3) in Structured Text (ST). Even older, existing systems can be configured, managed, and updated with the help of Opensyde. Via the numerous pre-installed widgets in the tool, data available via CAN or Ethernet can be displayed graphically and used in HMIs (human machine interface) or cloud solutions. Numerous convenient functions such as current controlling and ramp functions for outputs or frequency averaging for inputs are already integrated. Additional libraries simplify system integration. An 8 MiB flash memory, 2 MiB RAM, and a 32 KiB EEPROM are available for the customer application.

Figure 3: The brain of the machine: CANopen-capable control unit ESX.4cs-gw (Source: STW)

BHS Intralogistics used STW support and consulting during the development of the iShuttle to get the most out of the programming environment and to build a standards-compliant safety architecture. "Despite Covid-19 and the associated contact bans, STW service was there to help us with advice and support, providing various online seminars. This helped a lot with the system design," recalled Tristan Warias.

The iShuttle from BHS Intralogistics is a high technology solution for one of the fastest changing industries of our time. Anyone who has had the chance to experience a swarm of autonomous vehicles working together knows what an impressive sight this is. STW's flexible and safe control solutions are fundamental to this exciting experience. The iShuttle is another example of a successful partnership between an innovative machine manufacturer and the automation experts at STW. ◀

Source

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CAN FD circuit board reference design

Analog Devices (AD) provides printed circuit boards (PCB) and components for development of CAN FD based applications. This article shows details and evaluation of a CAN FD circuit board.

CN-0401 circuit evaluation board (EVAL-ADM3055E-ARDZ) is an Arduino Uno compatible isolated CAN FD communications port. It offers a possibility to add CAN FD communication to new and existing designs. The described evaluation procedure of the CN-0401 is performed using the Arduino-based development board (EVAL-ADICUP3029).

Circuit function

The circuit (Figure 1) shows the CN-0401 Arduino Uno form-factor platform connected via an existing serial peripheral interface (SPI) to the standalone MCP2518FD controller from Microchip and the ADM3055E CAN FD transceiver from Analog Devices. According to the manufacturers, this circuit enables CAN FD bit-rates of up to 8 Mbit/s. The CAN FD controller can operate in the Classical CAN or CAN FD mode. It is tolerant to CAN FD frames when operating in the Classical CAN mode.

The transceiver provides integrated signal and power reinforced isolation. The integrated DC-to-DC converter draws power from the logic side to power the CAN channels and the transceiver. Thus, no external power on the CAN lines is required. The EMC-robust (electromagnetic compatibility) transceiver has a common-mode range of ±25 V_{DC}, which exceeds the corresponding requirement given in ISO 11898-2:2016. It also offers a high tolerance to localized ground potential differences when receiving CAN frames. Integrated ESD (electrostatic discharge) protection on CAN-High and CAN-Low pins complies with IEC 61000-4-2. Providing a ±40-V_{DC} fault protection, the pins can withstand erroneous wiring and short circuits to 24-V_{DC} systems.

Depending on application requirements, CAN connections may be made with different cable types e.g. unshielded twisted-pair or shielded cables. An ideal CAN network daisy chains one node to the next and has terminations at both ends. The CiA 303-1 document gives recommendations for CAN(open) cabling and connector pin assignment e.g. for the 9-pin D-Sub connector, as used in the shown circuit.

The switchable termination circuitry connects a 120-Ohm split-termination with a common-mode filtering capacitor between the CAN lines. Switchable termination allows to configure (via software) the termination location when the conditions on the CAN network have changed. Additionally, the circuit can be configured at the runtime to enter a reduced power stand-by mode. In this state, the transceiver responds only on a defined wake-up sequence from a remote node according to ISO 11898-2:2016.

Circuit description

Fast loop delay and bit-rate: During the arbitration phase of a CAN FD frame, the maximum bit-rate is limited by the ▷

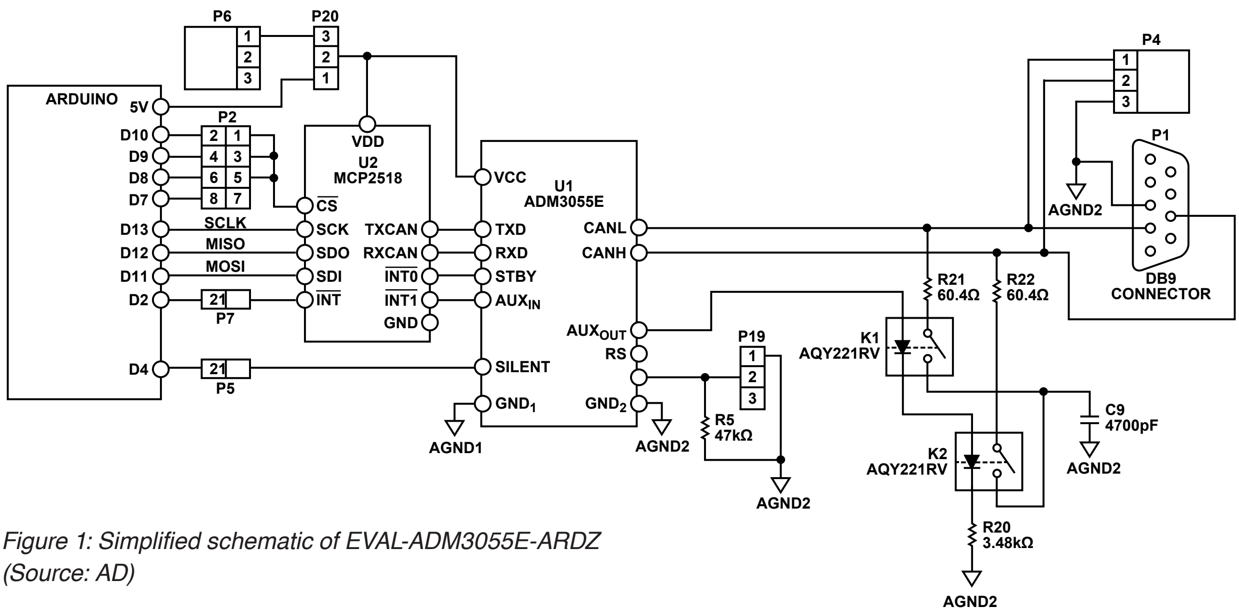

Figure 1: Simplified schematic of EVAL-ADM3055E-ARDZ (Source: AD)

longest total signal propagation time between two furthest nodes on the network. As illustrated in Figure 2, the signal path starts when the Node A CAN controller begins with the transmission. This signal first passes through the Node A transmitter, then propagates over the cables, then through the receiver of the furthest node B, and finally reaches the furthest CAN controller. As the receiving node B may also transmit during the same bit, the signal propagation delay from Node B to Node A has to be considered as well. The highest propagation delay determines the possible maximum bit-rate of the arbitration phase.

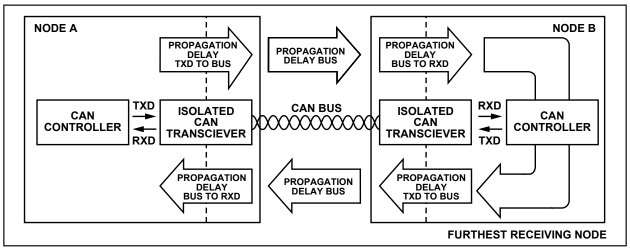

Figure 2: Total signal propagation delay (Source: AD)

Propagation delay along the bus lines increases with the cable length and enlarged construction. Cable lengths are typically determined by the nodes' mounting locations. Therefore, this portion of signal propagation delay becomes basically fixed. The propagation delay through the transceiver's receive and transmit circuitry is called loop delay. The ADM3055E transceiver has a maximum loop delay of 150 ns, which is an industry-leading small value, claims AD. This allows the network designer to dedicate less of the bit time to the transceiver. These time savings can contribute to higher arbitration bit-rates, longer bus cables, or longer bus signal settling time for added communication robustness at any arbitration bit-rate.

The maximum bit-rate in the data phase of a CAN FD frame, by contrast, is not determined by the propagation delay, but rather by the network signal quality. Reflections, due to impedance mismatches and cable stubs, are among the factors limiting the data-phase bit-rate in multiple-node networks. Data-phase bit-rates of 2 Mbit/s are a popular conservative choice for multiple-node CAN FD networks. The ADM3055E transceiver can operate at up to 12 Mbit/s in the data phase. This enables fast data transfers for point-to-point connections, and is suited for future bit-rate requirements.

Standby mode and remote wake-up: The CAN FD controller and the CAN FD transceiver can be set to the standby mode with commands issued by the development platform over the SPI bus. On receipt of the standby command, CAN FD controller sets itself and the transceiver to the standby mode. Here, the transmit functionality of the transceiver is disabled and its output is set to a high-impedance state.

The transceiver can only be taken out of the standby mode by the local CAN FD controller. However, the transceiver responds to the remote wake-up calls made by other nodes. The remote wake-up pattern is defined in ISO11898-2:2016. It can be sent in the arbitration field or in the data field of a CAN FD frame and has to meet the timing requirements of the transceiver. When the remote wake-up pattern is received, the RxD pin of the transceiver toggles in response to the data on the CAN FD bus.

The state changes on the RxD pin are used to trigger an interrupt to the CAN FD controller. When the transceiver receives the remote wake-up pattern, it does not exit the standby mode. While development it can be determined whether to respond, or to toggle the standby pin of the transceiver to discontinue reception of the low-speed data and to return to the standby mode until the remote wake-up pattern is received again. In the standby mode, the isolated auxiliary channel of the transceiver latches in the last state. Transceiver's integrated DC-to-DC converter continues to operate providing power to the bus side circuitry.

Isolation: Harsh environments, lengthy physical separation, and different power supply sources between nodes can (and often do) have different local ground potentials. The different potentials cause currents flowing through the ground wire causing common-mode offsets and noises. Isolation of the physical bus lines breaks the ground loops and eliminates these problems. The ADM3055E transceiver breaks ground loops and carries system level safety certification for the 5-kVRMS signal and power isolation between the CAN FD node and the CAN bus lines. For applications requiring lower isolation capabilities, the ADM3057E is available. For applications where bus-side power is available, ADM3056E is a reinforced signal isolated solution.

Switchable termination: For the best signal integrity, termination has to be implemented at both ends of a CAN network. Switchable termination allows to configure the termination location via software. This is useful for on-the-fly network reconfiguration when nodes are removed or added.

To keep the network reliability as high as possible, termination circuitry may not restrict the common-mode range. The termination circuitry may also not be affected by the common-mode range of the signal i.e. the termination circuitry must remain off when set to off and remain on when set to on. To meet the required circuit characteristics, the termination circuitry on the EVAL-ADM3055E-ARDZ evaluation board floats with the transmitting node using very compact optically-isolated SPST (single pole single throw) solid state relays (SSR).

Controlling the relays from the auxiliary isolated channel of the transceiver means that the relays do not bridge the isolation gap. Thus, the relays are not required to provide a safety isolation function and can have the smallest possible package to save the printed circuit board (PCB) area.

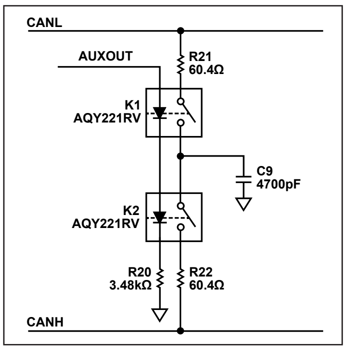

Figure 3: Switchable 120-Ohm termination resistance using Photomos relays controlled via an auxiliary channel (Source: AD)

The 120-Ohm termination resistance (Figure 3) can be accomplished with a single resistor. However, splitting the resistor into two 60-Ohm resistors offers an inexpensive measure of electrostatic discharge (ESD) protection to both relay pins exposed to the CAN. Implementing the switchable termination circuit with a second SSR allows for addition of a filter capacitor. The latter interacts with the split termination resistors to provide a low-pass filter, reducing the common-mode noise on the bus.

Silent mode and slope control mode: The CN-0401 circuit supports bit-rate detection via a software-configurable trial and error function. This is possible in conjunction with the silent mode of the transceiver. Silent mode disables the transceiver's transmit channel and allows a CAN controller to produce error frames while attempting to synchronize to the bus bit-rate without to interrupt the bus traffic. The CN-0401 circuit provides access to the transceiver's slope control mode. For low-speed signaling, slope control decreases the slew rate of the CAN-High and CAN-Low recessive-to-dominant transitions. Decreasing of the slew rate minimizes ringing and electromagnetic interference (EMI) caused by fast edges. The slope control mode should not be used for high-speed signaling.

Circuit evaluation and test

This section outlines a simple evaluation procedure for the EVAL-ADM3055E-ARDZ using the EVAL-ADICUP3029 development board. More information on the hardware and software setup is available on the company's website.

Equipment needed

- PC with a USB port and operating system Windows 7 (32-bit) or higher
- Serial terminal (e.g. Putty or Tera Term)
- Two EVAL-ADM3055E-ARDZ circuit evaluation boards
- Two EVAL-ADICUP3029 development boards
- Crosscore Embedded Studio or pre-built .hex file

Getting started

1. Open the CN0401 project in Crosscore Embedded Studio
2. Check that all user-defined settings are correct, as detailed in the EVAL-ADM3055E-ARDZ user guide
3. Build the project and upload the project to the ADICUP3029 board (alternatively, copy (drag and drop) the pre-built .hex file into the ADICUP3029 board mass storage device).

Functional test block diagram: Figure 4 shows the functional block diagram of the test setup. The PCB-tethered node software sets up a command line interface (CLI), which is commanded via a serial terminal running on a PC. Through the serial terminal, the user is able to command other nodes and send a remote wake-up message. ▷

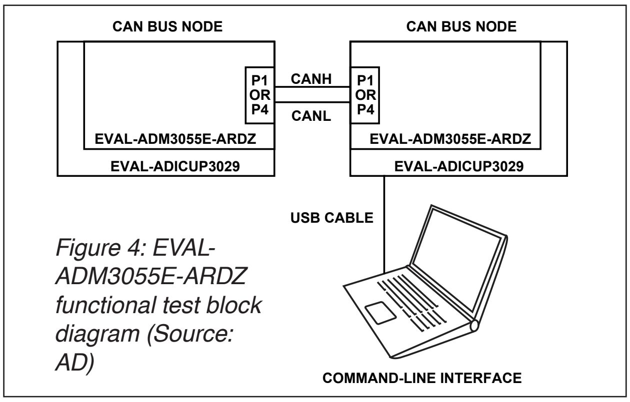

Figure 4: EVAL-ADM3055E-ARDZ functional test block diagram (Source: AD)

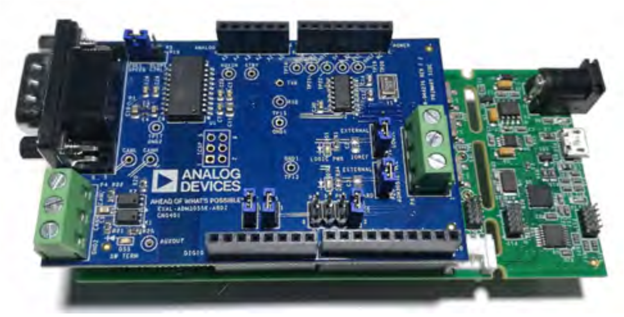

Figure 5: CAN node setup using EVAL-ADM3055E-ARDZ and EVAL-ADICUP3029 (Source: AD)

Test setup: A CAN node is set up by mounting the EVAL-ADM3055E-ARDZ atop the EVAL-ADICUP3029 using the Arduino-compatible headers, as shown in Figure 5.

Communication and remote wake-up test: With the sample software built and loaded on two different CAN nodes, the two boards (when connected) communicate with each other through a CAN FD connection. Figure 6 shows a two-node CAN connection.

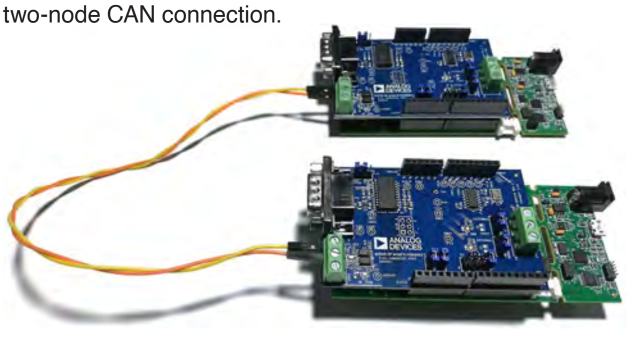

Figure 6: Two-node CAN connection test setup (Source: AD)

Default arbitration and data bit-rates are 500 kbit/s and 2 Mbit/s, respectively. The boards are connected to the PC via a USB cable. Each node has its own CLI running on a serial terminal. This configuration sets up a two-way CAN FD communication between the devices acting as two independent CAN nodes.

At first, the nodes are in sleep mode. Via the CLI a node can be commanded to wake up and to send an Ascii message via CAN. The message transmission has a timeout of 5 s and is cyclically sent until it is acknowledged by the other node. The message, particularly the slower arbitration phase, wakes up the other node. The latter acknowledges the message and displays it on the serial terminal connected to its node. Then, both nodes reenter the sleep mode.

Figure 7: Screenshot of a message displayed on the serial terminal (Source: AD)

When connected to a PC, each CAN node can be commanded to perform a communication loopback test. The CAN controller is placed in external loopback mode wherein the transmit line is internally connected to the receive line. The CAN node transmits a custom message and checks if it receives the same message. If the loopback message is received, the message is displayed in Ascii art on the CLI and the LEDs on the ADICUP3029 flash. A screenshot of the received message in the serial terminal is shown in Figure 7.

of

Source

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Potential for greater efficiency with CANopen Lift

Digitalization and networking offer new possibilities for modern elevator hydraulics. With the ongoing development of its valve technology in conjunction with sensors and serial network systems, Bucher Hydraulics provides solutions in this field.

Viewed as a development platform, the intelligent iValve with CANopen Lift interface offers far-reaching improvement potential for hydraulic elevators – a potential that is already being exploited in the area of time- and cost-saving installation and commissioning. In addition, elevator manufacturers can develop new service concepts thanks to remote monitoring and the predictive maintenance that results from it. All in all, these advantages increase competitiveness and secure the elevator manufacturer's market position.

"Better to start right now than to wait for the total industrial revolution that is coming," is the motto for new technologies in hydraulic elevators. If the elevator concept, which has been reliable for decades, is to be enhanced to meet future requirements, this will be a job best done step-by-step. The primary objective is not Industry 4.0, but rather reductions in workload, such as shorter commissioning times and faster data access, which result from networking and implementing digital technologies. The prerequisite, however, is that the right basic components are selected. This will ensure that, in the event of later adaptations or extensions, all avenues are open. As a specialist in the development of components for hydraulic elevators, Bucher Hydraulics uses its decades of product know-how as well as its industry insights to show elevator manufacturers valuable potential for increasing efficiency.

Right from the start of the development and construction of the iValve, this background knowledge led the specialists to attach great importance to economic efficiency and future application possibilities. The valve works with a particular learning algorithm that balances and optimizes basic settings and current travel data. This intrinsic intelligence ensures that the car starts faster and can approach the destination floor without any delay. This shortens the travel time and raises energy efficiency. For these reasons, the valve has become the new benchmark in elevator hydraulics.

Several display variants

The integrated electronics include all the parameters for setting speed, acceleration, etc. Up to now, elevator technicians have been able to change these values locally at the elevator system using a hand-held terminal. This means, however, that specific hand terminals must not only be available for components such as the drive, elevator controls, or doors, but must also be available immediately for on-site interventions, which in turn involves additional costs.

Figure 1: The iValve series of valves feature a CANopen Lift interface, all operation-relevant information such as parameters and status data can be accessed via the elevator controller (Source: Bucher Hydraulics)

In addition, the know-how for operating the hand terminals must be available. For this reason, Bucher Hydraulics has now taken a significant step forward and is the first manufacturer of elevator hydraulics to use the CANopen Lift interface as a future-proof method of connecting the valve to elevator controllers.

In conjunction with the iAccess valve function and the built-in sensors for measuring pressure and temperature, the iValve can now also communicate directly with the elevator controller via network protocol. Travel commands are transmitted rapidly, operating data and status/error messages can be displayed at the elevator controller, and valve parameters can also be changed right at the elevator controller. This technology offers several advantages. During installation and commissioning, the decreased amount of cabling saves time and also reduces the possible sources of errors. In addition, a fault memory provides all the relevant information that helps

Figure 2: Bucher Hydraulics offers drive solutions for hydraulic elevators. The sophisticated, sector-specific solution using the iValve shortens elevator installation and commissioning times and enables proactive responses (Source: Bucher Hydraulics) ▷

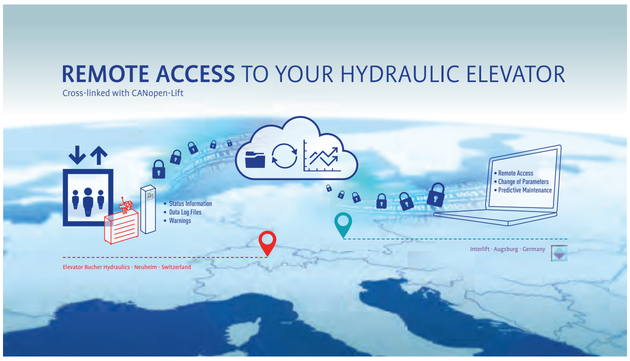

Figure 3: The valve technology helps users to implement predictive maintenance concepts thanks to a continuous awareness of the condition of the equipment (Source: Bucher Hydraulics)

technicians to make informed decisions about how to correct an elevator fault.

The data can be displayed in different ways depending on the elevator controller. The spectrum ranges from two-line displays, through TFT displays and touch screens to smartphone apps via Bluetooth and is constantly being developed and extended. Users, thus have a clear understanding of the system's minute-by-minute operation without the need for any additional equipment and can intervene using the existing elevator controller.

The diagnostic functions, which are based on the information made available and then transmitted via serial network systems, form the basis for the predictive maintenance or needs-oriented service that has the aim of increasing the system availability. The early planning of predictable measures saves time, travel, and costs, as potential faults can be identified long before a possible stoppage.

Applying the valve technology of the iValve in conjunction with CANopen Lift, elevator manufacturers can use it to suit the particular requirements that the elevator must fulfill, and configure it for future customer needs. In further steps, systems can increasingly be networked and digitalized, thus making them smarter. Of course, this also applies to the modernization of existing hydraulic systems.

Starting with the implementation of the valve together with its standardized interface, the spectrum extends to the complete networking of the elevator components via the Internet. There, remote access also enables the data to be monitored on a central computer in a control room and retrieved as necessary. In this way, fast access is guaranteed – for example, in public buildings with a high level of traffic, such as train stations or shopping centers. To protect against cyberattacks, Internet connections can be individually restricted by means of selected access rights.

In the age of the Internet of Things, predictive maintenance solutions are the new core competence. There are various versions of these predictive maintenance solutions, but the objective is always the same: avoid costly downtime, allocate maintenance resources more effectively, and plan maintenance activities more economically. Digital real-time monitoring helps to ensure that components are no longer needlessly repaired or replaced just because it is ▷

Q&A with Huebschmann: Elevators featuring future-oriented technology

Christoph Piorek, Huebschmann Aufzuege

Huebschmann Aufzuege in Korbach has 130 employees and has been manufacturing its own elevators as well as components for other manufacturers' elevators for over 40 years. In addition, this medium-sized family business provides complete coverage in the service area. The fact that the company has its own Design and Development department enables it to implement short-leadtimes and unusual customer requirements. Huebschmann is one of the users of the Bucher Hydraulics iValve valve technology featuring a CANopen Lift interface. Christoph Piorek, authorized signatory (Prokurist) of the elevator specialist in Korbach since 2009, explained how prepared the company is already for the future networking of elevator components.

Q: What were your main reasons for choosing the iValve with CANopen Lift from Bucher Hydraulics?

Christoph Piorek: Modern technology was at the top of the list. The iValve hydraulic drive has intelligent control algorithms and the function of an additional safety valve is already incorporated. Instead of the usual "turn the screw in by feel", the adjustment is purely electronic, so the settings are reproducible and easy to document. As well as that, analysis tools such as the travel-curve recorder and data memory make it easier to troubleshoot any problems.

Q: Is this technology, with its networking possibilities, something that you've been waiting for?

Christoph Piorek: Yes, absolutely, because with the increasing use of electronics in elevator construction, the CANopen Lift standard helps us to use different components from different manufacturers together in one system. In the past, drive systems often required their own handheld terminal or even a PC for convenient commissioning and service. If our control system can also be used as the operating terminal for the drive, that's a considerable simplification. By operating the elevator via CANopen Lift, the amount of wiring in the rest of our control system can be reduced to just the safety circuit. The control card is connected to the CAN network and just runs.

Q: As an elevator manufacturer, what advantages do you get from the new valve technology in the areas of installation and commissioning and in terms of service and the service concept?

Christoph Piorek: First of all, the preset drives plus their self-learning optimization give fast commissioning at the customer's site, and often there is no need to send a "system specialist" to the site. Given the shortage of skilled workers, this is very important for our company. What's more, the technology also shows advantages in the service area. Integrating the controller into the serial network system allows remote access to the drive system, so a detailed fault analysis is also possible from a distant location. In addition, we can detect possible upcoming faults at an early stage and even before they actually occur. This, in turn, is the basis for us to be able to successfully implement current "hot topics" in the service area such as condition-based maintenance or the even further-reaching predictive maintenance.

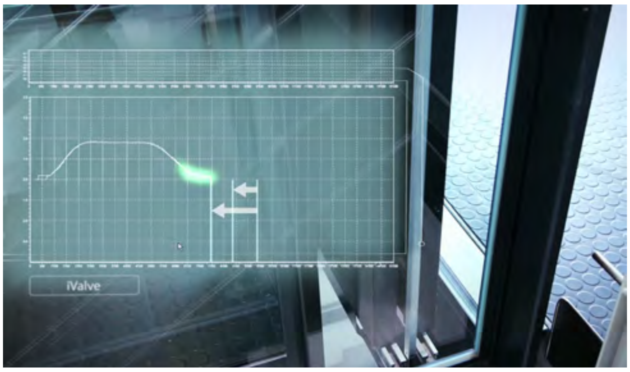

Figure 4: iValve is a self-learning elevator control valve with standardized protocol (Source: Bucher Hydraulics)

specified in the schedule. Instead, and even without an on-site visit, the actual need for repairs can be identified at an early stage through continuous awareness, so the previously customary inspection visits are no longer necessary and deployment plans can be optimized.

All in all, digitalization and networking change not only the manufacturing of elevators, but also their commissioning and the entire service process, in which reliable and life-extending maintenance measures are key factors. Maintaining a hold on a market position and/or aiming for company growth already demand that elevator manufacturers have larger sales territories involving longer journeys. Integrating new technologies into the business model can significantly improve the management of these larger territories, as service personnel can be deployed more efficiently due to up-to-date information. The intelligent iValve from Bucher Hydraulics already offers the prerequisites needed to meet all these challenges and to be able to press the strategic UP button to Lift 4.0 at an early stage. ◀

Source

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Development of CAN-based rescue stairs

Rosenbauer has improved its rescue stairs which implement a CAN system. The company explains its new way of software development and introduces how all relevant characteristics of the 33-ton and about one million Euro rescue stairs were put in one controller.

When it comes to operations on or around the runway, time is of the essence: Rosenbauer developed an Aircraft Interior Access Vehicle, better known as rescue stairs in order, to be able to come to the aid of passengers and crew as quickly as possible in the event of an emergency. The vehicles have been designed to arrive on the scene of emergency quickly and dock with the aircraft equally fast. This is not only to enable evacuations in a controlled manner, but also to allow firefighting and rescue teams quick and safe access. Rosenbauer put a lot of effort in the development of the rescue stairs. The company reduced electronics, cooperated with other companies, and used a new way of software development.

Figure 1: A medical emergency, smoke in the cabin, or an evacuation - in the event of an incident on board an aircraft, action must be taken quickly; Rosenbauer has improved its rescue stairs for this purpose (Source: Rosenbauer)

Set-up times and safety

The E5000 and E8000 rescue stairs have already proven to be the ideal vehicles that are equipped for such scenarios. During the development, particular focus was placed on safety, operation, and setup time. As a result, the crew can select an individual door at the respective type of aircraft, to automatically extend the rescue platform to the correct height. The approach to the aircraft is supported by audible and optical aids, such as distance sensors, camera imaging, and an overhead window, to ensure the best possible view in every scenario. The platform can be adjusted to match the aircraft fuselage, and the side rails can be manually docked onto it. This makes alignment easier and ensures gap-free and secure access. Thanks to sophisticated technology, the platform and steps are held in a horizontal position regardless of the incline of the staircase. This means that both evacuations and rapid access by rescue teams can be undertaken safely.

Improved operation concept

Rosenbauer, however, continuously strives to improve products that have already been refined. This is precisely why the operating concept of the rescue stairs have been revised and the latest lighting technology integrated. Feedback from Rosenbauer's customers has had a significant impact upon this further development. The crew is now given a 10-inch HD touchscreen display, both in the driver's cab and on the rescue platform, through which the rescue stairs can be controlled.

The display was specifically developed together with Ginzinger Electronic Systems for the usage on rescue vehicles. The embedded system is based on an i.mx6 dual-core processor for automotive application. All functions can also be operated via hard keys if the environmental conditions or the worn gloves do not allow a touch operation. Further the display features a brightness sensor to adjust its brightness and color theming to ensure not to irritate a driver during a night drive and still be easy to read in direct sunlight with its brightness of up to 1 000 cd/m². With the RBC LCS (logic control system) operating system, the rescue stairs fit into the Rosenbauer product family. This makes it easier for crew members to switch between the different vehicle types. The operation system is based on CAN technology. The control panel in the driver's cab is ▷


Figure 2: The rescue stairs in action (Source: Rosenbauer)

mounted on a swivel arm that can be rotated to either the driver's or passenger's side. In this way the operator can have everything exactly where they want it to be.

Rosenbauer's new way of software development

Not only the operation has been overhauled, but the CAN system has also been implemented from scratch. A reduction of ECUs (electronic control unit) was achieved by using ECUs from TTControl, which are certified for safety purposes. The risk and hazard analysis showed that there are safety requirements up to PLd. In the first generation of the product, the controllers available within Rosenbauer with an established software framework had PLb only. Without the software framework, the controllers could not have been configured with the Rosenbauer service tool. Due to this constraint all safety features, like emergency stops had to be hardwired. Some safety features could only be met by software, like the tipping of the machine or level- ▷

Figure 3: With the simulation, the development iterations can be driven to a maximum and the programmer gets off all the external influences (Source: Rosenbauer)

ling the platform. These features had to be programmed on different CPU (central processing unit) types and compared via CAN in terms of redundancy. This setup led to an electronic system with many relays and many different controllers. Hence it was very difficult to handle in point of servicing and troubleshooting.

Now Rosenbauer achieved to put all safety features in a single TTControl ECU which features the redundancy internally. Safety requirements like tilting and levelling are programmed by two independent developer teams, one team at TTControl in Brixen and another team at Rosenbauer in Leonding. On the ECU the multitasking real-time system Safertos is operating both developed algorithms in parallel. The safety algorithm stops the machine all at once. The application algorithm takes care that the machine never moves at a position where the safety algorithm would need to take control and warns the user in advance on the display. As the TTControl ECUs combined with the Safertos guarantees the freedom of interference, the non-safety relevant application software can be maintained and deployed on the same controller. This is enabled without the need to repeat all the safety certification on every new software version. As Rosenbauer's products are varying greatly based on final customer, this is an important feature to reduce the maintenance efforts of the safety software.

Electronics reduction

With this safety architecture we achieved a reduction of ECUs from six units of three different types to three units of identical type. Another reduction of electronics was performed on the hydraulic valves. In the previous generation was a valve manifold, where each valve had a small electronics module integrated, which was controlled via an individual PWM signal. Now the complexity of the system was reduced by eliminating the electronics on the valves, but to use two outputs for each valve. The TTControl ECU has everything on board for this purpose. It has sufficient outputs and each PWM output can measure its current. The accuracy of the current measurement is sufficient for moving the valve in every position via current control without a sensor on the valve. Only actuators with position control are equipped with sensors, while all speed control is performed without sensors.

In this project, pioneering work was done in the way of application software development at Rosenbauer. A virtual model was created for the whole hydraulic system, with two PWM signals for each actuator as an input. All sensor signals were measured in reality, and used as outputs like hydraulic pressures, end positions of the actuators, CAN signals and current values. This model was used in two ways:

On one hand, it was deployed by automatic code generation onto another TTControl ECU to enable the safety software development team to perform software tests without travelling to the rescue stairs. All relevant characteristics of the 33-ton and about one million Euro rescue stairs were put in one controller.

On the other hand, the model was used to develop the application software. Therefore, the hardcoded current and position controllers from TTControl were imported into Simulink. In this way, external delivered code pieces and the model of the mechanics were operating in one PC simulation, independent of the production status of the machine and with no hardware at all. Before this model-based approach, at Rosenbauer the software development started on the desk as well, but nobody knew how it would behave on the machine. The real work started at the point of time when the programmer sat in the machine. With the new method the programmer knows that the application software is functional and must search the differences or the missing testcase during the commissioning only. It turned out that everything working in the simulation also worked in real life, like the tricky part of finding correct resting positions and keeping the first and last stair of the mainframe telescope in a flat position.

Simulation before release

With the simulation, the development iterations can be driven to a maximum and the programmer gets off all the external influences. A machine of this size can be run only outside, so the programmer is exposed to the weather and to the noise of the diesel engine. For each iteration, the software needs to be downloaded to the controller and interesting variables must be monitored and plotted for each iteration. In practice the days get very long and are very stressful, as it usually takes very long until all I/O checks and mechanical and electrical installations are 100 % finished.

The delivery date never changes, but all the other processes take longer as planned, which must be compensated by extra working hours of the programmer. With the simulation, the software development and testing can be done efficiently in the office, decoupled from noise, stress, and bad weather conditions. The quality and the possibility of maintenance of the generated software is much better this way.

At the software development itself Matlab/Simulink/Stateflow and the embedded code generator give the programmer the possibility to concentrate on the software design. The hard work of writing the code after drawing the stateflow diagram is automated by the code generator. Even if it turns out during the commissioning that there was a wrong assumption in the model, adding an extra state or ▷

DIN 14700 and DIN 14704

The DIN German standardization body specifies two CAN-based solutions for firefighting body applications. The DIN 14700 standardizes a CANopen-based network for add-on devices. Such devices are exchangeable and provide therefore the same functionality. The specified PDOs are not configurable regarding the communication and mapping parameter sets. The add-on device includes water cannon, light mast, frequency inverter, and electrical power supply.

The DIN 14700 standard is currently under review. It is written in German language. The DIN 14704 standard specifying the gateway to the in-vehicle networks is written in English language. It is based on the DIN 4630 standard also provided in English language. It is under development and uses a J1939-based application layer. The specified Parameter Group messages are referenced (DIN 4630) or specified in detail including the mapped parameters. *hz*

transition is only a matter of drawing and has no big impact on a software that is already programmed. Another advantage of the model-based design is that the drawings of the software can be understood by the customer service and other stakeholders, who are no programmers. The self-speaking drawings in Simulink/Stateflow can be exported to html and published to everyone.

Fine-tuning for optics and lighting

Rosenbauer's engineers have also further improved the scene and staircase lighting systems. Instead of the previous LED spotlights, the latest LED light strip technology is used, which ensures more homogeneous and improved illumination of the steps and the surrounding area. This further increases the safety of passengers and emergency crews, especially when operating in the dark. The rescue stair's rear has also been given a facelift: the lighting has been adapted to the appearance of the rest of the Rosenbauer fleet, and thus fits seamlessly into the modern and visually appealing vehicle range.

The innovations integrated into the rescue stairs are yet another example of how consistently Rosenbauer works on the further development of existing products and the introduction of new technologies. Rosenbauer is committed to providing maximum safety and efficiency in emergencies to emergency crews around the world with the best products for their daily work. ◀

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CAN cables in pharmacy picking systems

With the sliding cabinet system, pharmacies can store their medications in a space-saving manner. The system stores up to 60 000 packaging units in a little space and picks them automatically according to order.

(Source: Adobe Stock)

A patient who visits a doctor with an acute complaint usually receives a prescription that they must take to the nearest pharmacy. The logistic performance of the pharmacies that our patient must use (and there are almost 20 000 of them in Germany) often receives insufficient appreciation. A regular pharmacy has about 20 000 medications on hand (large ones have up to 60 000) and receives up to five deliveries each day. Throughput is high, storage is extremely complex, and space is usually limited. That is why picking systems have established themselves: they allow the pharmacy staff to request a medication at the touch of a button and give it to the customer after a very brief waiting period with additional information such as an explanation of the medication.

Sliding cabinet system

The systems designed by Gollmann Kommissioniersysteme in Halle (Saale), Germany are assuming a prominent place in this market because they are especially compact. Other systems work with fixed channels in which the handling system moves, but Gollmann has developed movable cabinets that open up channels wherever goods are being picked or delivered (Figure 1).

This principle doesn't just save space. It also allows customized adaptation to spatial restrictions in all dimensions. There must be flexibility and reliability despite the pronounced manufacturing complexity. Gollmann meets this requirement with two factors. The company has great in-house vertical integration and engages high-quality industrial partners as suppliers. After all, the picking systems must not fail, and a single system completes about 15 million movements over the course of 15 years of operation in a pharmacy.

This principle has worked very well for Gollmann. Daniel Gollmann founded the company in 2006. In 2007, the first full business year, the company installed 12 systems. Currently, 250 systems leave the company's large assembly halls each year – that's one every single business day. Sven Ronneberger, the company's technical manager, said: "At the beginning we made fixed versions of our system. Now we are flexible in all dimensions and offer systems that can store 60 000 articles or more. No two systems are alike." Gollmann has been working with Igus for more than ten years in the selection and optimization of moving cables and energy chains.

Figure 1: Gollmann commissioning systems are remarkable for their design that can be adapted to each individual case (Source: Gollmann Kommissioniersysteme)

Mobile energy supply for individual cabinets and grippers

Each cabinet is driven by a stepper motor that must receive energy and, critically, signals. For instance, each end position is queried with a proximity switch. This means that there are many moving cables (Figure 2) and a corresponding variety of energy chains, since the storage and retrieval unit arm (Figure 3) and the gripper at the end of the arm (Figure 4) require energy.

Figure 2: Each sliding cabinet receives its energy supply and signal routing from an E065 energy chain and Chainflex cables (Source: Igus)

CAN cables

Early on (in 2007), Gollmann decided to include Igus E065 energy chains and has stuck with them ever since. A short time later, the decision was made to buy the cables from Igus, too. Since Gollmann picking systems use CAN cables to communicate, the focus was on the network cables from the Chainflex product range. CAN is mainly used in automation technology. In addition, CAN systems are also found in industrially used vehicles such as forklifts or lifting work platforms. CAN cables are available for different fields of application. In general, CAN cables are often installed fixed in machinery and equipment, so that cables with a solid conductor or a flexible conductor consisting of seven strands can be selected.

For applications in the energy chain, it is necessary to use CAN cables with fine stranded wires. In addition, a cable structure tailored to the movement in the energy chain is necessary, so that secure data transmission is guaranteed over the years. This is why Chainflex cables have become established especially in equipment and machines such as robots, packaging machines, production machines, and machine tools.

The Chainflex cable product range offers a variety of CAN cables. In total there are 13 different CAN cable types from seven different cable ranges available for different applications. All CAN cables have been developed for continuous movement in the energy chain. Depending on the requirements, users can choose between different PVC, PUR, and TPE outer jackets. The different cable series offer different performance levels, so that the right cable can be chosen for each application area in order to achieve the maximum service life. All CAN cables have one thing in common: They are subject to the same quality standards. Here it does not matter whether it is a cost-effective cable of the CF888 range, or a cable for the highest demands and smallest bend radii as is the case with the CFBUS.LB range. Therefore, Igus also gives a 36-month functional

Figure 3: Energy and CAN signals reach the RBG axes through energy chains (Source: Gollmann Kommissioniersysteme)

guarantee on all chainflex CAN cables with a service life of up to 10 million double strokes.

The topic of the maximum transmission length of cables is often underestimated. In general, caution should be exercised, as the maximum cable length can vary greatly depending on the type of cable. A cable for fixed installation always has a lower dampening than flexible cables, which is designed for permanent movements. As a result, the transmission length is lower than with a cable for fixed installation.

Depending on the cable range, Chainflex CAN cables are mechanically designed for travel distances of up to 400 m or more, but the data-rate of the network system decreases with increasing cable lengths. For fixed installation, copper cables can reach up to 500 m. Then the maximum transmission speed is still 125 kbit/s, while with a cable length of 40 m a data transfer rate of 1 Mbit/s is still possible. For flexible CAN cables for the energy chain, experience shows that one cable length can be significantly shorter. Depending on the transmission speed, up to 50 m is possible for a moving CAN cable. However, this length may vary up and down depending on the environmental conditions and application requirements.

Last year, Gollmann ordered almost 30 km of cables from the Chainflex CF211 series alone. A specially developed Chainflex measuring system cable based on the CF211 series provides many advantages in cable processability. Igus developed the entire cable range especially for moving, demanding energy chain use, and tested it under real-world conditions. The company grants a unique guarantee of 36 months or up to 40 million double strokes (for the Chainflex CF298, for instance).

These usage quantities provide representative information about reliability – and the conclusions are clear. Ronneberger said, "In our picking systems delivered worldwide, we have installed more than 20 000 energy chains so far, and they work very reliably, without malfunctions or maintenance." This is important because the businesses that invest in a Gollmann system are entitled to a "carefree package" in which the manufacturer assumes the responsibility (and costs) for all servicing, including unplanned failures, for the average service life of 15 years. Gollmann, supplements this guarantee with an additional expense allowance and three hours of on-site service anywhere in Germany.

This makes the selection of long-lasting, fail-safe components a question of the pharmacy's own interest, which is why the collaboration began with endurance tests on Igus energy chains and cables at Gollmann's test facility. At the same time, the components were compared, using the parameters specified by Gollmann, to the empirical values Igus has collected from more than 27 years of tests in its 3 800 square meter test laboratory. The tests focus on bend radius, which is often very small because of the compactness of Gollmann systems.

Standardization does not always cut costs

Originally, Gollmann used only those Igus energy chains and cables that had especially small bend radii and could therefore be used universally. This is reasonable from the point of view of standardization. But two years ago, the design engineers worked with Igus to assess the possibility of using two levels of quality and less robust series for larger bend radii. As such information as a comparative service life calculation showed, this proved helpful, and Gollmann has since saved tens of thousands of euros each year on cable costs.

Figure 4: The gripper system is equipped with a E065 chain; The chain also carries a vacuum line for suctioning the packaging to be picked (Source: Igus)

Ronneberger considers such projects important and valuable. "Our Design and Research and Development staff appreciate the open, long-term partnership with Igus. Another advantage, and one that we do not take for granted, is the product training that Igus conducts personally on site." A further optimization project looked at Chainflex cables that are customized for applications such as measuring technology. It improved the cables' connector assembly, reducing costs and assembly time. Assembly effort plays an important role in component selection more generally. "We pay a lot of attention to processability. Chain filling must be convenient, for instance." And with the E065, it is. The cables are simply pressed along the outer radius to the chain interior.

Creative alternative uses

The picking systems' innovative rolling cabinet concept has attracted interest from outside the pharmaceuticals industry. Ronneberger said: "We are increasingly planning projects for entirely different applications such as managing tens of thousands of samples for a producer of spice mixtures in the food service industry." In another case, a metalworking company is storing turning and milling tools in a Gollmann system. If a tool is worn, the worker retrieves a replacement (if they have user privileges), and the system can track tool service life effectively. A completely new and relatively novel application is pop-up stores that are set up in locations such as shopping centers and can be used as attractive, space-saving, temporary points of sale. So, ideas are clearly coming not only from Gollmann design engineers, but from sales staff as well. Igus gives Gollmann a moving energy supply and signal routing partner that is just as agile.

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Approach for node-ID negotiation in CANopen

The increasing complexity and size of CANopen (FD) networks create new challenges on how to decide which node-ID should be used. This article discusses a theoretical approach how devices in a CANopen (FD) network could negotiate their node-ID by themselves.

The assignment of a node-ID to a CANopen device is an essential requirement. Without a node-ID a CANopen device is unable to communicate over services defined in CiA 301 and CiA 1301. Without a valid node-ID in the range of 1 to 127, a CANopen device would never leave the NMT (network management) sub-state reset communication. Since the node-ID has to be unique in the network, there has to be a way to configure the node-ID value. Neither CiA 301 nor CiA 1301 specify a way to configure this value. There are various solutions on the market how this can be achieved.

Some manufactures use hardware solutions on their devices, such as dip- or rotary-switches, or encode plugs. Others, use some kind of proprietary software configuration. All of these solutions need more or less knowledge about the system where the devices are integrated. Another way to configure the node-ID is specified in the document CiA 305, CANopen layer setting services (LSS). This specification describes services and protocols for identifying CANopen devices and assigning node-IDs, which can be used by a so called LSS manager (formerly named LSS master) or some configuration tool.

The CANopen application profile for building door control, CiA 416, also specifies a procedure for claiming node-IDs by the devices themselves. But besides that, this procedure is slow, it is also patented. The following theoretical approach for negotiation of node-IDs introduced by the engineers of Emotas Embedded Communication should be a starting point how to overcome most of the disadvantages of the other solutions.

Systems without a superordinated manager

Some systems are designed very flexible. That means that a system could be built with different combinations of devices, exactly meeting the needed requirements.

Sometimes, it could be enough that only two devices are needed, sometimes much more, and sometimes there are multiple of the same device type in a network. An example of such kind of systems are heating systems based on CANopen. They can include multiple sensors and controllers depending on location and size where the system is installed.

When creating the devices for such a system, it is not clear which kind of device could be unique in the system, so it can operate as a CANopen manager. The CANopen manager is the device with NMT manager functionality plus additional functionality, for example, the LSS manager.

One way to assign node-IDs without an LSS manager is when integrating the system. But this leads to a static system, without a real plug-and-play possibility. And, in case some parts are added, or have to be replaced, an unused node-ID has to be assigned to the replaced part, which might be impossible for a service technician.

Another example are battery clusters, which are capable of plug and play. The only devices in this network are the batteries themselves. They are physically all of the same device type and have the same software. In such a system, the node-ID is irrelevant to the system, but is required for CANopen communication.

Systems with a superordinated manager

In generic CANopen systems with a superordinated manager, there are also possibilities that the actual distribution of the node-IDs is not relevant for the functionality of the system.

Examples are the CANopen application profile for energy management systems, CiA 454, or the CANopen application profile for special-purpose car add-on devices, CiA 447. These specifications use the LSS Fastscan procedure, defined in CiA 305, to detect devices and to assign node-IDs to them. With LSS Fastscan devices can be only detected one after another, and in the worst case of completely unknown devices it will take 128 messages to verify every single bit of the CANopen LSS address. With a response-timeout of 10 ms, it would take 1,28 s to detect one single device.

New approach

The idea behind this approach is that, in systems which do not depend on the node-ID distribution, the devices negotiate their node-ID themselves. The idea is not new, for example in the document J1939-81 of the SAE (Society of Automotive Engineers), there is a description of a so-called address claim procedure. In this procedure, the devices in a CAN-based network negotiate the addresses (node-IDs), depending on values of the Name field. The problem here is that this procedure uses the 8-byte data field of the CAN frame. This led to the fact, that, in case two or more devices are claiming the same address, it could lead to collisions on the CAN network. In our approach, we are trying to avoid this by not using the data field: All the information exchanged between devices are encoded in the identifier field.

The main requirements for this procedure are that the software of the devices is able to send and receive CAN data frames in classical extended frame format (CEFF). Because most modern CAN FD controllers support sending and ▷

receiving this kind of data frames, this approach works in CANopen FD as well. It is also important that the software can distinguish between extended and basic frame formats.

Usage of the CAN-Identifier

The CAN-Identifier (CAN-ID) of an extended data frame has 29 bits available. For our approach we only need 13 bits. The least significant 13 bits are used for the node-ID negotiation. The 13 bits are divided into two fields, the least significant 8 bits are used as data field, and the most significant 5 bits as data code. Table 1 illustrates the usage of the CAN-ID.

Table 1: 29-bit CAN-ID usage

Bit 28 to 13	Bit 12 to 8	Bit 7 to 0
reserved	Data code	Data field

Using 13 bit of the 29 bits of an extended CAN-ID means that 44 % of the bits are required, but the following

$$\frac{2^{13}}{2^{29}} = \frac{8.192}{536.870.912} = 0{,}00001525$$

formula shows that only 0,0015 % of all possible extended CAN-IDs are reserved for this service:

The data code defines the meaning of the data field content. If the most significant bit is set to 1, the data field contains parts of the CANopen object 1018_h, identity object. For this procedure to work, all four sub-indices are required. Table 2 shows which part of the identity object 1018_h is transmitted with which data code.

Table 2: Data code correlation with 1018_h

Data code	1018_h data
10000_b	Sub-index 1, bit 0 to 7
10001_b	Sub-index 1, bit 8 to 15
10010_b	Sub-index 1, bit 16 to 23
10011_b	Sub-index 1, bit 24 to 31
10100_b	Sub-index 2, bit 0 to 7
10101_b	Sub-index 2, bit 8 to 15
10110_b	Sub-index 2, bit 16 to 23
10111_b	Sub-index 2, bit 24 to 31
11000_b	Sub-index 3, bit 0 to 7
11001_b	Sub-index 3, bit 8 to 15
11010_b	Sub-index 3, bit 16 to 23
11011_b	Sub-index 3, bit 24 to 31
11100_b	Sub-index 4, bit 0 to 7
11101_b	Sub-index 4, bit 8 to 15
11110_b	Sub-index 4, bit 16 to 23
11111_b	Sub-index 4, bit 24 to 31

Due to the binary coding of the data code, it is very easy to implement the algorithm for accessing the value of the identity object. Bit 3 and 4 are the sub-index number - 1, and bit 0 and 1 are the byte number of this sub-index.

Two data code values are dedicated for the flow control of the process and are listed in Table 3.

Table 3: Flow control data code

Data code	Name
00001_b	ReqUsedNodeId
00010_b	ActUsedNodeId

The data code ReqUsedNodeId is used to start a new process, whereby the data field contains 0. The resulting message with extended CAN ID 100_h will trigger all devices with a valid node-ID to respond with ActUsedNodeId and their own node-ID in the data field. Figure 1 shows the basic concept of asking the network for the node-IDs, which are already used in the network.

Negotiation process

The negotiation process is only performed by nodes with an invalid node-ID. All nodes with a valid node-ID are ignoring the messages with the most significant bit in the data code field set to one. If a device participating in the procedure, receives a negotiation message, it compares the value according to Table 2 with its own equivalent. In case the received value is higher than its own value, the device continues the negotiation.

In case the received value is smaller as its own equivalent, the negotiation is stopped on this device. And, the device has to wait until the running negotiation is done. It can detect this by setting a timeout (e.g. 100 ms), and restart this timeout every time it receives a negotiation message. In case a device is able to transmit all 16 messages, which are needed to transmit all 128 bits of the identity object, it will then announce the preferred node-ID to the network by using ActUsedNodeId data code message.

Figure 2 shows a complete negotiation cycle with a timeout value of 100 ms before and after the actual negotiation and an additional 5-ms delay between every negotiation message.

Node-ID conflicts

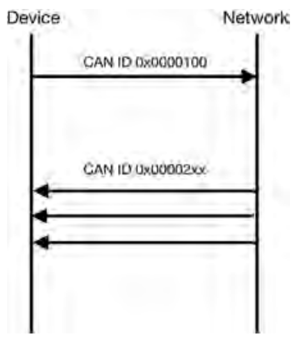

Figure 1: Initializing negotiation (Source: Emotas)

In case a device successfully negotiated a node-ID, but another device indicates by the ActUsedNodeId message the very same node-ID, the receiving device sends out the same ActUsedNodeId, sets its pending node-ID to the invalid node-ID, and enters the NMT state reset communication. Because the other device received this message, it loses its node-ID too. Both devices can restart the negotiation process again. The losing device of this negotiation shall alter the preferred node-ID for the next cycle to a node-ID not yet present in the system.

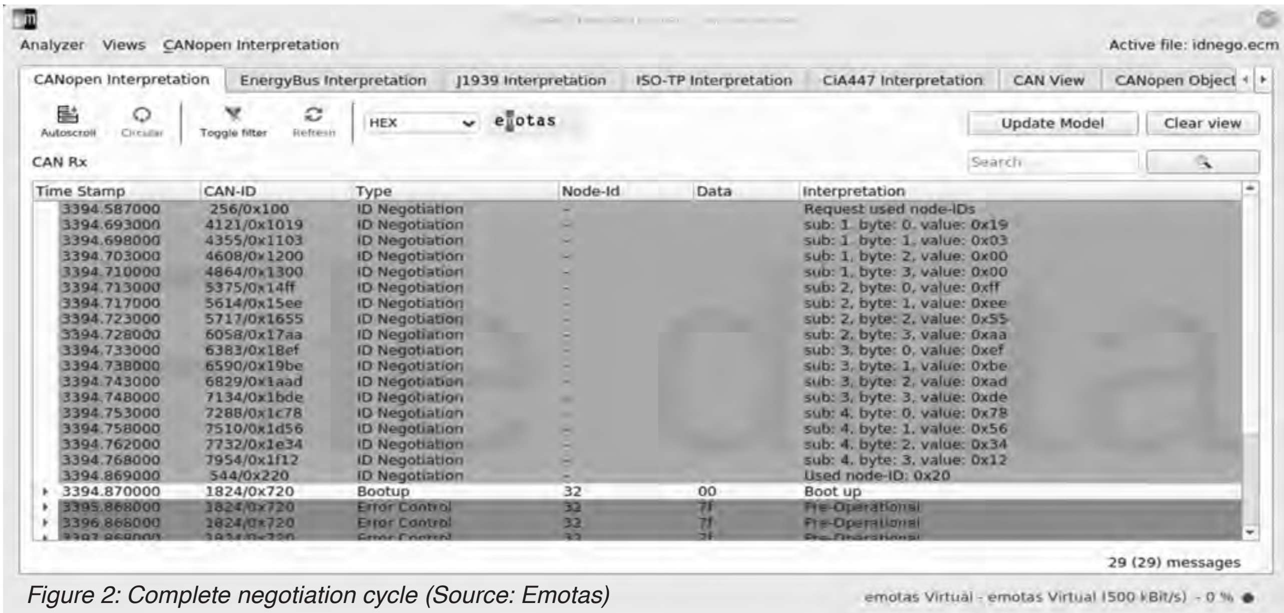

Figure 2: Complete negotiation cycle (Source: Emotas)

Table 4: CAN Trace simulation example (Source: Emotas)

Time (s)	CAN-ID	ide	l	d
0,000000	256_d / 100_h	EXT	0	–
0,105000	4121_d / 1019_h	EXT	0	–
0,106000	4121_d / 1019_h	EXT	0	–
0,110000	4355_d / 1103_h	EXT	0	–
0,111000	4355_d / 1103_h	EXT	0	–
0,115000	4608_d / 1200_h	EXT	0	–
0,115000	4608_d / 1200_h	EXT	0	–
0,119000	4864_d / 1300_h	EXT	0	–
0,121000	4864_d / 1300_h	EXT	0	–
0,125000	5375_d / $14FF_h$	EXT	0	–
0,126000	5375_d / $14FF_h$	EXT	0	–
0,130000	5614_d / $15EE_h$	EXT	0	–
0,130000	5614_d / $15EE_h$	EXT	0	–
0,135000	5717_d / 1655_h	EXT	0	–
0,136000	5717_d / 1655_h	EXT	0	–
0,140000	6058_d / $17AA_h$	EXT	0	–
0,141000	6058_d / $17AA_h$	EXT	0	–
0,145000	6383_d / $18EF_h$	EXT	0	–
0,146000	6383_d / $18EF_h$	EXT	0	–
0,149000	6590_d / $19BE_h$	EXT	0	–
0,155000	6829_d / $1AAD_h$	EXT	0	–
0,161000	7134_d / $1BDE_h$	EXT	0	–
0,165000	7201_d / $1C21_h$	EXT	0	–
0,170000	7491_d / $1D43_h$	EXT	0	–
0,174000	7781_d / $1E65_h$	EXT	0	–
0,181000	8071_d / $1F87_h$	EXT	0	–
0,279000	576_d / 240_h	EXT	0	–
0,280000	1856_d / 740_h	–	1	00_h
0,282000	256_d / 100_h	EXT	0	–
0,283000	576_d / 240_h	EXT	0	–
0,387000	4121_d / 1019_h	EXT	0	–
0,392000	4355_d / 1103_h	EXT	0	–
0,397000	4608_d / 1200_h	EXT	0	–
0,402000	4864_d / 1300_h	EXT	0	–
0,406000	5375_d / $14FF_h$	EXT	0	–
0,412000	5614_d / $15EE_h$	EXT	0	–

Time (s)	CAN-ID	ide	l	d
0,417000	5717_d / 1655_h	EXT	0	–
0,422000	6058_d / $17AA_h$	EXT	0	–
0,426000	6383_d / $18EF_h$	EXT	0	–
0,432000	6590_d / $19BE_h$	EXT	0	–
0,437000	6829_d / $1AAD_h$	EXT	0	–
0,442000	7134_d / $1BDE_h$	EXT	0	–
0,447000	7423_d / $1CFF_h$	EXT	0	–
0,451000	7491_d / $1D43_h$	EXT	0	–
0,456000	7781_d / $1E65_h$	EXT	0	–
0,462000	8071_d / $1F87_h$	EXT	0	–
0,561000	577_d / 241_h	EXT	0	–
0,562000	1857_d / 741_h	–	1	00_h
1,280000	1856_d / 740_h	–	1	$7F_h$
1,562000	1857_d / 741_h	–	1	$7F_h$

Table 4 shows a CAN Trace simulation example of two nodes negotiating their node-IDs. The difference in the 1018_h parameter revision number causes the one node to stop the negotiation and to restart again after the first one is ready.

The main goal is still to find a reliable, robust, and fast solution to assign node-IDs in plug-and-play systems to extend the network during its lifecycle. This theoretical approach should only be a basis for discussion on how to achieve this. With the discussed process it is possible to assign node-IDs to devices without the need of a dedicated LSS manager. The usage of extended CAN-IDs makes it possible that only 16 messages are needed, and that the process does not create CAN network collisions. ◀

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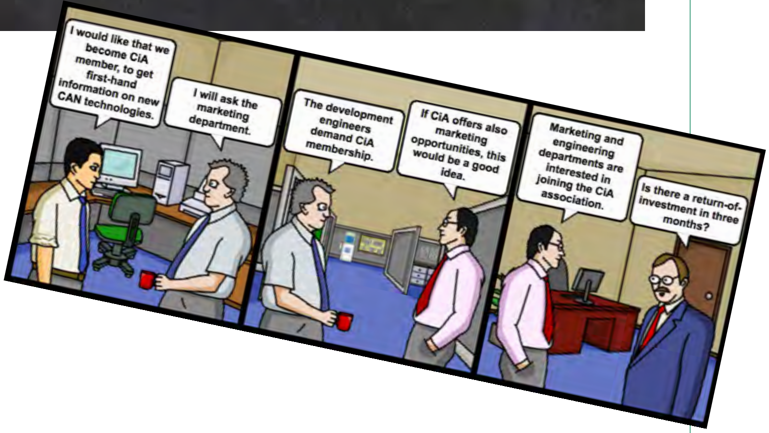
Facts & Figures

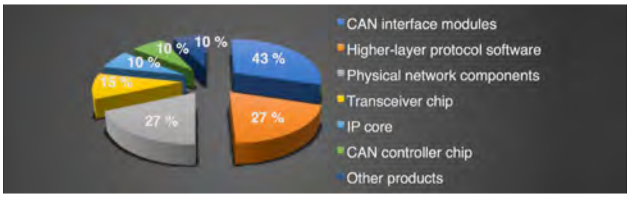


416

More than 400 CiA members provide CANopen products. About 100 members support J1939-based hardware and software. This includes Isobus (ISO 11783 series) and NMEA 2000 (IEC 61162-3) compliant devices. About 50 members offer equipment with Devicenet (IEC 62026-3) interfaces.

82

There are 82 CiA members offering CAN semiconductors, generic CAN interface, protocol stacks, and other CAN interface components. They are so-to-say technology enablers providing semi-finished products for the design of CAN device interfaces.



Technology enabling CiA members (Source: CiA)

440

Category	Number *
Device supplier	440
Sub-system manufacturer	194
Service supplier	95
Technology enabler	82
System manufacturer (OEM)	70
Tool supplier	35
Research	22
Software solution provider	17
End-user	3

2021-06-30

* Multiple answers (number of members: 700)

Classification of CiA members – multiple answers possible (Source: CiA)

From the 700 CiA members, 440 supply CAN devices and 194 are sub-system vendors. But there are also 70 original equipment manufacturers as well as three end-users.

145

Drives and motion control vendors (145) are the biggest group of the 440 devices suppliers in the CiA membership followed by 133 host controller vendors, which include electronic control units (ECU) for road and off-road vehicles. The number of sensor and measuring device manufacturers is 116. There are 107 members offering generic I/O devices and 96 produce human machine interfaces (HMI).

51

The community of elevator manufacturers within the CiA membership counts 51. It is one of the largest special interest groups developing the CiA 417 CANopen application profile for lift control systems. Another strong special interest group is subsea with 29 CiA members specifying the CiA 443 CANopen for SIIS level-2 devices.

50%

Half of the 700 CiA members are located in Germany, Austria, and Switzerland. There is also a strong CAN community in North European countries. USA and Canadian members make 10 percent of the membership, followed by 9 percent situated in Italy.

Country/region	%
DE/CH/AT (298/39/18)	51
SE/NO/DK/FI (26/16/15/13)	10
US/CA (58/8)	9
IT (58)	8
CN/HK/TW(31)	4
UK (20)	3
NL (18)	3
RU/PL/CZ/RO/RS/LT/EE (3/7/3/1/1/2/1)	3
FR (14)	2
ES (11)	2
JP (9)	1
ROW (30)	4

17th international CAN Conference recorded videos available

From Classical CAN via CAN FD to CAN XL

CAN in Automation (CiA) has announced the opportunity to get access to the video-recorded presentations of the 17th international CAN Conference (iCC). This way, anyone who missed the conference is still able to experience it.