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.

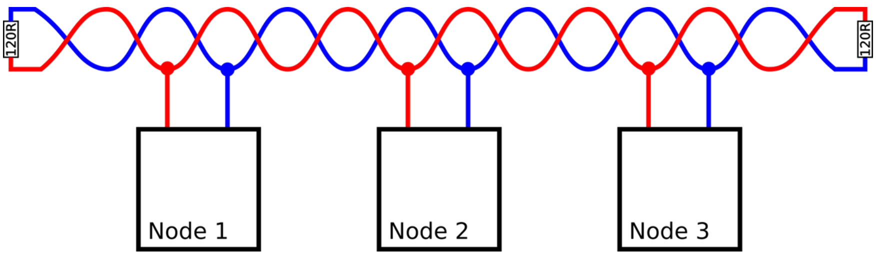

Figure 1: General design of a CAN network (Source: Gemac Chemnitz)

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), ▷

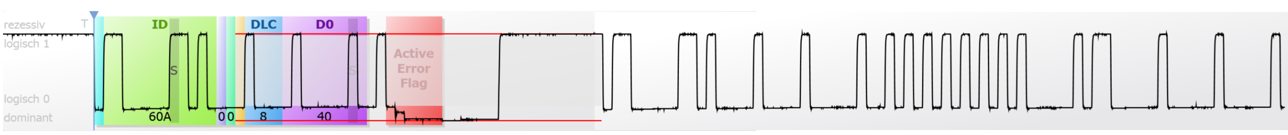

Figure 2: Active error flag with subsequent message repetition (Source: Gemac Chemnitz)

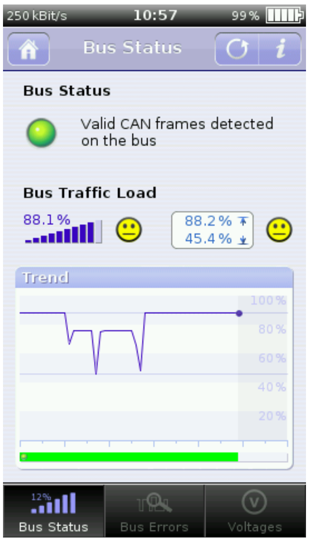

Figure 3: CANtouch measurement - Very high bus load (Source: Gemac Chemnitz)

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.

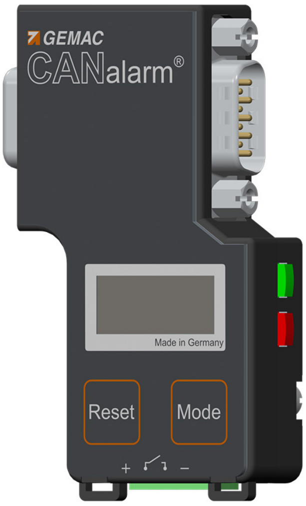

Figure 4: CANalarm (Source: Gemac Chemnitz)

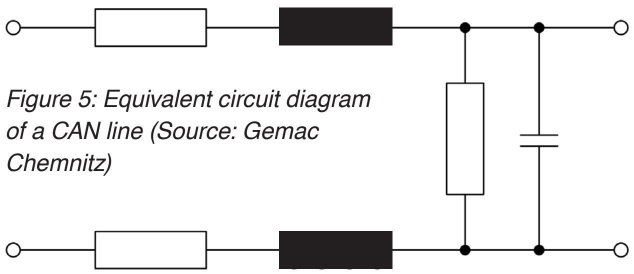

Figure 5: Equivalent circuit diagram of a CAN line (Source: Gemac Chemnitz)

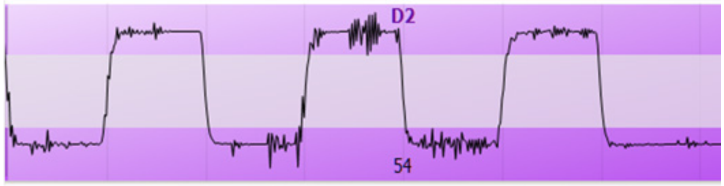

Figure 7: CAN differential signal with interference and reduced disturbance-free voltage range (Source: Gemac Chemnitz)

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.

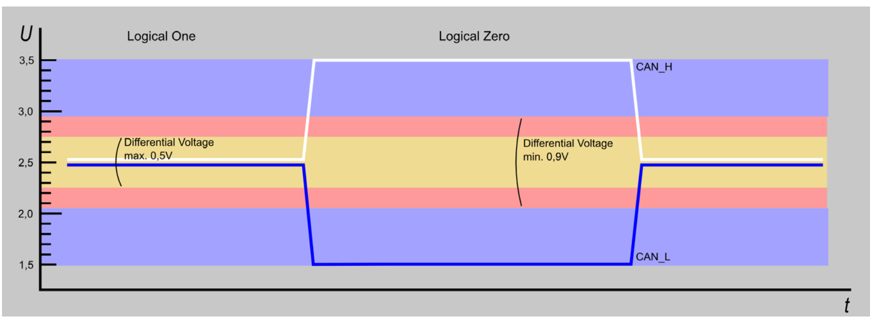

Figure 6: Formation of the CAN level of the differential signal (Source: Gemac Chemnitz)

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. ▷


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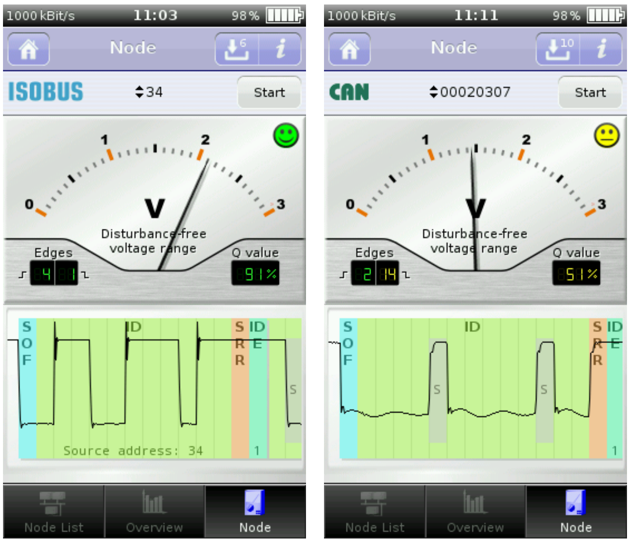

Figure 8: CANtouch: Quality value measurements on individual nodes (Source: Gemac Chemnitz)

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.

Author

Ralf Meischner
Gemac Chemnitz
info@gemac-chemnitz.de
www.gemac-chemnitz.com