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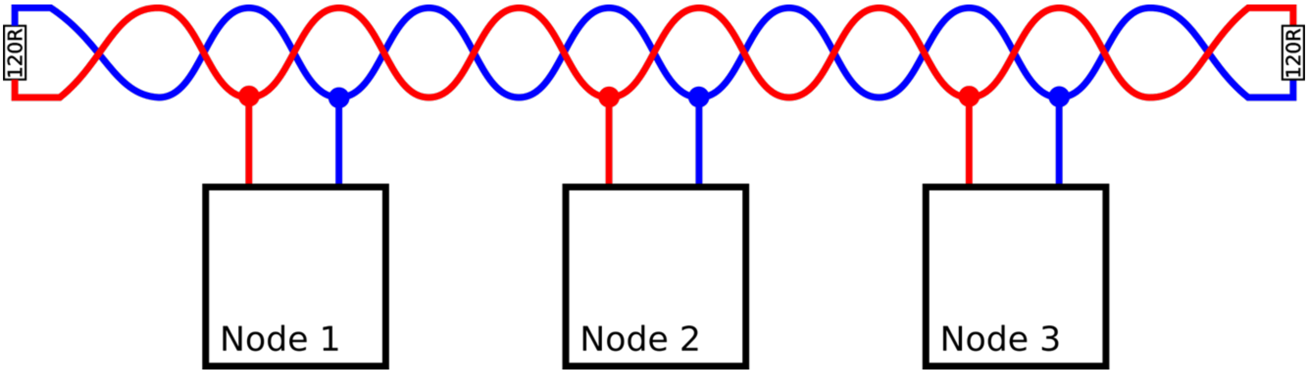
CAN diagnostic for machine availability

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.



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

The complete article is published in the September issue of the CAN Newsletter magazine 2021. This is just an excerpt.

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.

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

Limiting the bus load

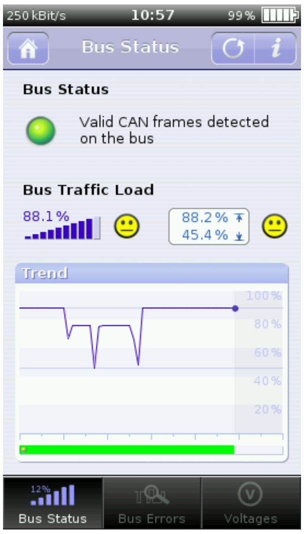
It must be an objective when designing and developing mobile machinery to keep the load in the central CAN system within a meaningful frame. Thus, sufficient time remains in case of error to repeat the message frames. Unfortunately, a lot of data is transmitted in many systems without first analyzing 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

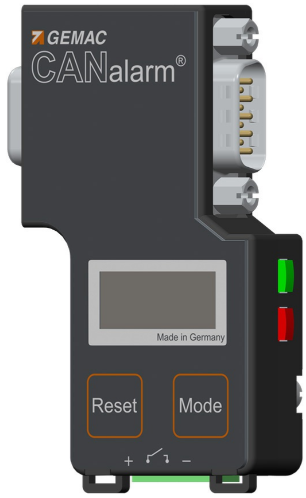
Measuring the bus load is simple and can be represented roughly by way of a CAN-to-USB interface. The bus load and the occurrence of error frames (where applicable), for example, can be monitored without the necessity of using a PC thanks to appropriate hardware modules, such as CANalarm from Gemac. 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



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

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.

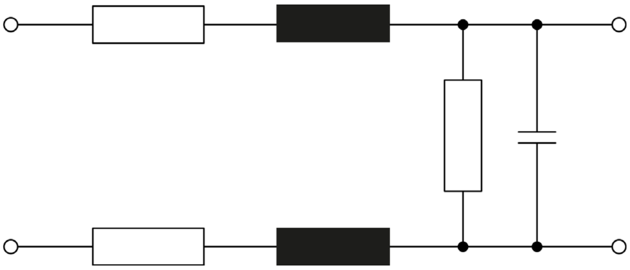


CANalarm (Source: Gemac Chemnitz)

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.

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.



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

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.

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