The Benefits of CAN for In-Vehicle Networking

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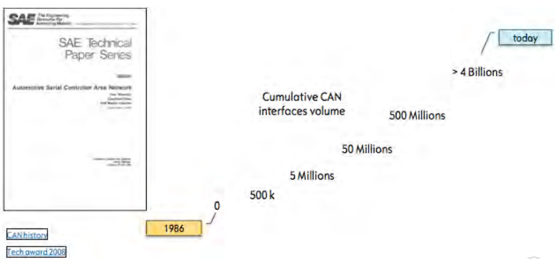
CAN is one of the most successful wired serial data communication protocols both in terms of volumes and in terms of acceptance across industry branches considering the past twenty years. It is the predominant bus protocol in today's and upcoming vehicles. This paper outlines protocol success factors, CAN protocol usage at GM/Opel, CAN benefits, and protocol improvement needs from an automaker point of view.

When back in 1986 Uwe Kiencke, Siegfried Dais, and Martin Litschel submitted their SAE conference contribution "Automotive Serial Controller Area Network" they presumably did not imagine what profound effect this would have both within and beyond automotive industry.

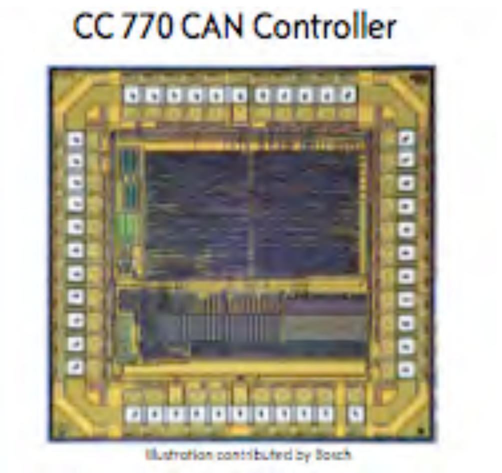


Even though the protocol was developed for automotive use cases, interestingly early adopters were companies outside the automotive industry. As an example one of the first series production use cases for the CAN protocol were textile machines and elevator control. For several years after protocol publication CAN interface total market annual volumes remained in the 100k's range, which are low volumes from the perspective of semiconductor manufacturers and large automakers.

20 years of steep acceptance growth

It took until mid of the 90's for CAN to advance to annual volumes in the single digit million range. At that time the first integrated CAN transceiver consistent to automotive EMC needs hit the market, the PCA82C250. Availability of an automotive suited bus transceiver was a significant milestone as it enabled protocol acceptance in the automotive industry, and Daimler was one of the early adopters there. In industrial automation the integrated bus transceiver was used for example in DeviceNet systems.
Early in the 90's it was typical that every major automaker had its own proprietary bus protocol. In the second half of the 90's there was a persistent acceptance growth in favor of CAN over alternative protocols such as VAN, ABUS, J1850, or BEAN. End of the 90's CAN had evolved to become the de-facto automotive industry standard data bus for several use cases such as communication between or/and within powertrain and chassis control domains. Additionally, some automakers used it as infotainment control bus. The majority of automakers was using the protocol in a more or less extensive way and CAN interface total market annual volumes entered the two digit millions range. In the last decade there was more significant volume growth for example as CAN usage expanded in automotive body controls. Today CAN is widely used

beyond passenger vehicles, such as for example in industrial automation, agricultural equipment, medical equipment, heavy duty trucks, avionics, marine electronics, E-bikes, and more. Total market CAN interface annual volumes have entered the three digit millions range.



Today's 8/16/32 bit microcontroller products frequently are equipped with one or more CAN interfaces and there is a wide offering of CAN bus transceiver products. More standards based on CAN are under development. As an example the automotive industry currently pursues a bus transceiver improvement in terms of a selective wakeup feature for the purpose to enable energy efficiency enhancement (ISO 11898-6). CAN protocol enhancements named CAN FD are in work to accommodate market demand for more bandwidth.

Characteristic	LIN	CAN	FlexRay
Bandwidth	-	o	+
Cold crank & engine autostart support	- Physical layer	+	o Re-integration
Required master functions	o Bus master	+	o Time master(s)
Bit error detection	-	o	+
Energy efficiency	+	o	-
Cost efficiency	+	+	o

Early in the last decade new bus protocols surfaced such as LIN and FlexRay. LIN needs one bus wire less compared to CAN and has accomplished acceptance as interface for some non-real time automotive sensors and actuators. LIN downsides for example are operation at crank and bandwidth constraints. FlexRay supports higher bandwidth compared to CAN, however it implies extra engineering effort, higher cost, plus – unlike CAN – there is no significant acceptance beyond automotive industry.

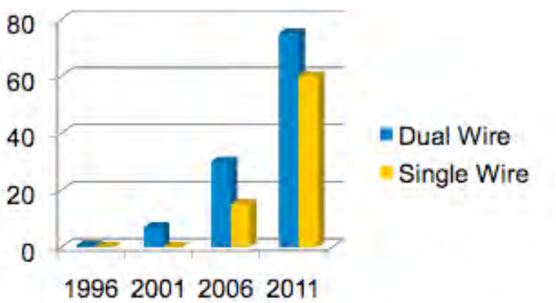
From technical perspective simplicity of use probably was one of the significant enablers for protocol acceptance. For example unlike many other data communication protocols regular CAN does not require bus master, time master, clock agreement prior to message start, message schedule, bandwidth reservation, network switches, or hubs. New messages and additional receivers for established messages are noticeably easier to accommodate compared to many other data bus protocols.

Fitness for real-time control

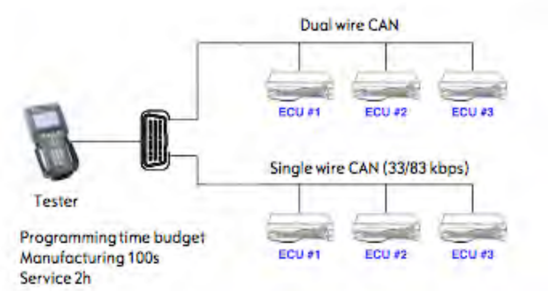
A second significant technical aspect was the protocol's suitability for real-time control. CAN supports non-destructive and message priority controlled bus arbitration. The protocol supports practically instant transmission for high priority messages such as for example for network-wide synchronization or degradation notification purpose.

From a non-technical point of view an essential success enabling factor were standardization activities such as performed at ISO, SAE, and last not least CAN in Automation users group. Standards enabled elimination of single source situations and contributed to evolvement of broad product portfolios in the hardware, software, and development tools domain.

CAN is in use at Opel since the mid 90's and serves as a multi-purpose medium bandwidth bus. Typical number of CAN interface instances per vehicle are 6 to 60 presently. Annual GM corporate CAN interfaces volume has grown higher than 100 millions. Protocol use cases include control and medium speed data transfer for domains like powertrain, chassis, body, and infotainment.



Opel uses CAN in two hardware variants: Dual-wire CAN (500 kbit/s, 125 kbit/s), and Single-wire CAN (33.3 kbit/s regular, 83.3 kbit/s for programming). Depending on feature content typically there are two to six CAN network instances in today's Opel/GM vehicles. As an observation there is an icreasing number of devices with more than one CAN interface for bandwidth expansion purpose. This indicates more bandwidth would be useful.



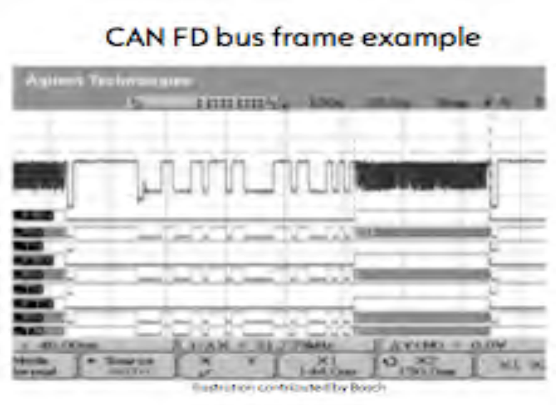
Multi-purpose medium bandwidth serial data bus protocols such as CAN enable sharing of status and sensor data across domain borders. This in turn enables consolidation of sensor inventory and holistic control or optimization of electrical system function. Further such bus network simplifies feature growth when new messages and new bus nodes are easy to accommodate. As a benefit nowadays it is not infrequent that new cross-domain features can be introduced without any hardware changes needed and with limited engineering effort. For illustration think of a feature upgrade from user controlled central door locking to user and vehicle speed controlled locking. Further, serial data buses enable limitation of wiring harness weight and connector pin counts.

Programming through single access point

As an additional benefit the bus enables programming of a two digit megabytes data size to CAN-connected devices via one vehicle diagnostics connector within less than an hour, enabling device deproliferation and contributing to work efficiency at production and service.

Data buses should effectively contribute to today's automakers strive for reduction in the areas of power consumption, weight, and wire count.
Robustness enhancements are desirable as more interference will come on board a

vehicle due to the advent of electric propulsion.
Higher bandwidth and messages with more than eight data bytes are needed in support of feature growth and programming size growth.
Further, there is an increase of features where circumstances that might compromise data communication need to be detectable prior to bus dropout, meaning there is demand for enhanced detection of significant inconsistencies and degradations for the purpose to enable deactivation of defined features when needed.
Finally, bus networks should exhibit graceful degradation to enable limp home for customer satisfaction considerations.



From an automaker point of view these are more specific relevant CAN improvement needs.
Physical layer and data link layer inconsistencies and degradations need to be detectable within a subnet before they can cause sudden stop of message transmission or/and when they compromise real-time behavior. For example whenever bus signal delay, bit-level resynchronization, or bus utilization approach operational or design intent limits this should be host-detectable. Identifier conflicts should be detectable. Further, the protocol should support switching between an upper and a lower bit rate for the purpose to enable accelerated programming or to enable limp home at presence of degradations. As a tentative figure for next generation a net data rate of roughly 70 bytes per millisecond and message data length of up to roughly 28 bytes would seem useful.

Over the past twenty years CAN has become one of the most successful bus protocol both in terms of volumes and acceptance across industry branches. It is the predominant bus protocol in today's and upcoming vehicles. Upgrades are needed for the CAN protocol and physical layer to enable continued growth. For example going forward the bus protocol should be upgraded for support of noticeable higher bandwidth compared to present. The CAN physical layer preferably should support device wakeup depending on message content also known as selective wakeup feature.

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