Automotive and industrial use cases for CAN FD

Dr. Tobias Lorenz

Author

Dr. Tobias Lorenz
Etas GmbH
PO Box 300220
DE-70442 Stuttgart
Tel.: +49-711-89661-0
Fax: +49-711-89661-107
tobias.lorenz@etas.com

Link
www.etas.com

Introduction
In 1987 Bosch introduced the Controller Area Network, which soon became one of the most popular in-vehicle network technologies and was used in many other industries. Today CAN is still the most commonly used network in the automotive area, but the latest vehicle systems with high data rates require the introduction of CAN FD (CAN with flexible data rate) as its successor.

The main advantage of CAN turned out to be a limiting factor for today's applications. Each CAN frame is acknowledged by the receiving nodes by sending an acknowledgment flag into the transmitted frame. Thus the sender gets a direct in-frame response on successful message transmission. However, this requires that the propagation time for sending the physical signal to the most distant node and back is not longer than the time frame for the acknowledgement signal itself. The propagation delay is mainly imposed by the transceivers and the cable length. Thus, there is a reciprocal relationship between the bit-rate and the propagation delay.

CAN was designed for a maximum bit-rate of 1 Mbit/s on a cable with a maximum length of 40 m. Due to the emission limits and immunity tolerances, it is commonly used with lower bit-rates. In passenger cars it is used with a maximum bit-rate of up to 800 kbit/s, while 500 kbit/s is more common. Commercial vehicles have larger topologies, thus using up to 500 kbit/s, but it is more common to have 250 kbit/s. As applications become more and more bandwidth-intense, CAN has to compete with more modern technologies such as Ethernet (bit-rates above 100 Mbit/s over a distance of 100 m). Beside the limited bit-rate, the maximum data field length of 8 bytes is also insufficient for today's applications. Transport protocols are necessary to transmit larger chunks of data.

With CAN FD it is possible to transmit a CAN frame with two different bit-rates. While the control data (arbitration, acknowledgement) is sent with the nominal bit-rate, the data itself is transmitted with a higher bit-rate. The data bit-rate only depends on the transmission characteristics and capabilities of the physical layer, not on the signal propagation delay. This concept provides backward compatibility with existing CAN controllers. The second improvement is that a data frame can have up to 64 bytes of payload. In addition, the requirement for transport protocols can be dropped in several use cases. CAN FD also introduces the CRCs (cyclic redundancy checks) for larger frames, which take the CAN stuff bits into account. This ensures that the safety level remains constant with a hamming distance of six. Following are some of the use cases that directly benefit or even require CAN FD communication.

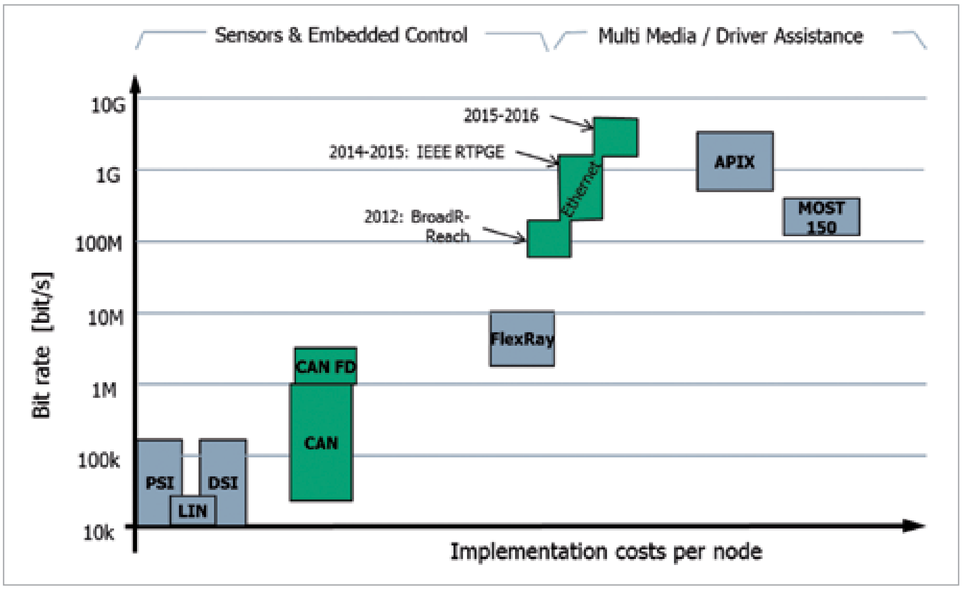

Figure 1: CAN FD provides a seamless upgrade path for CAN technology towards Flexray and Ethernet

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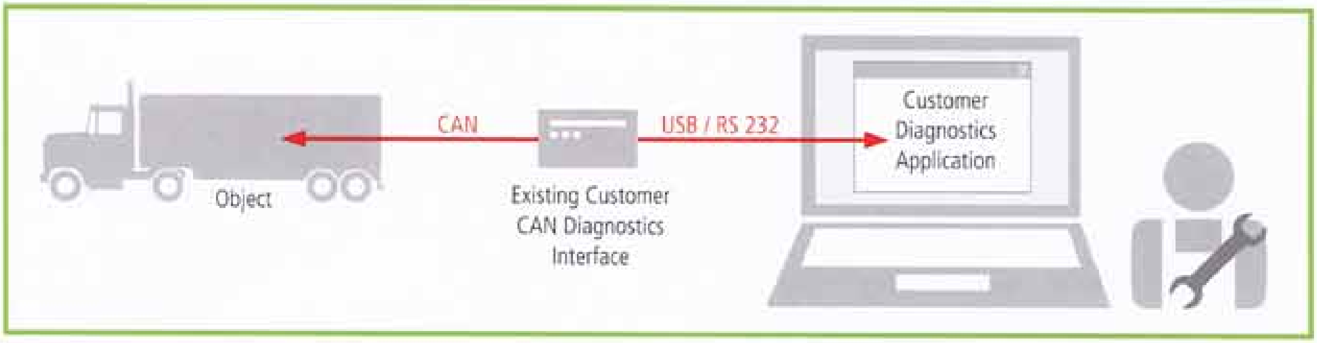
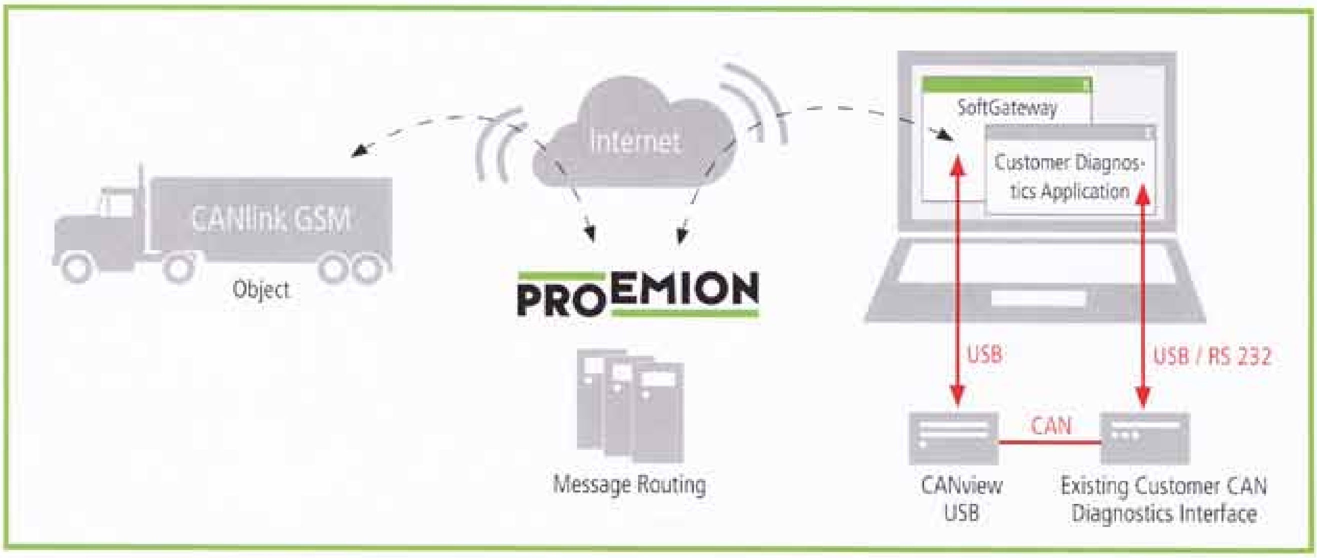


CAN data is read via cable connection – remote diagnosis is not possible.

PROEMION REAL-TIME TELEDIAGNOSIS



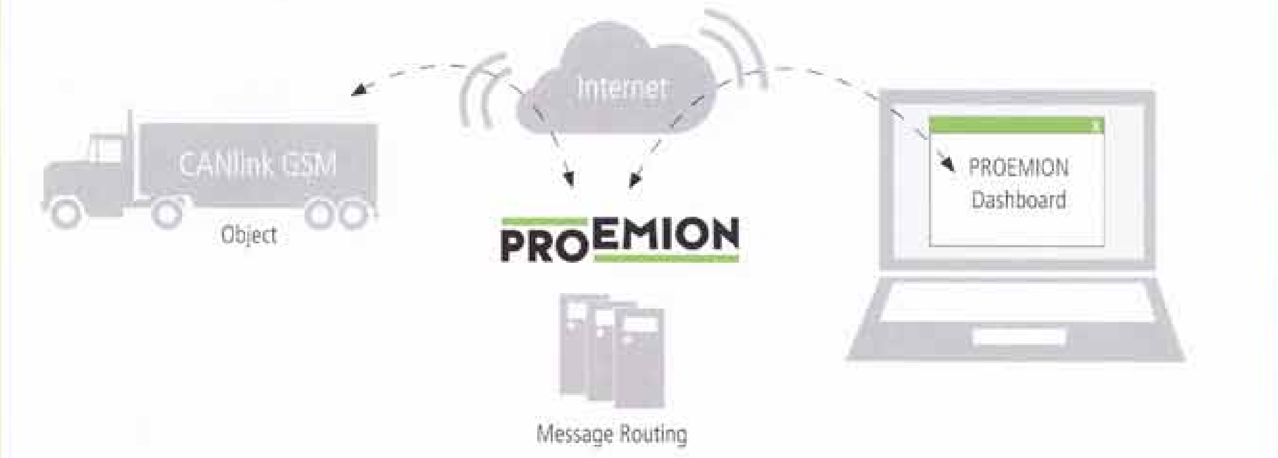
The PROEMION Real-Time remote diagnosis solution enables access to vehicle operational data, machines or remote objects in real time – anytime, anywhere. With conventional diagnostic systems, such data is only available on site. PROEMION Real-Time enables wireless connectivity with remote objects – regardless of distance. Global availability of diagnostic data not only facilitates error detection and prevention, but also allows a timely response to critical values. Errors can be rectified without costly and time-intensive on-site repairs, downtime is reduced or even avoided.

Advantages:

> wireless access – thanks to GSM / UMTS bridging
> immediate global diagnosis of vehicles and other remote objects
> PROEMION Real-Time compliments / replaces workshop diagnostics
> easy integration into existing hardware and software
> extremely time- and resource-efficient
> service-oriented solutions provide quick problem detection
> effective diagnostics

New Real-Time "Dashboard" feature –
A global telematics system – no additional hardware required

NEW: PROEMION REAL-TIME "DASHBOARD"



As an advanced version of our established PROEMION Real-Time solution, "Dashboard" – a new desktop application – provides optimal, extremely user-friendly representation of globally retrievable CAN data. Upon installing the PROEMION CAN-link GSM / UMTS module no additional hardware modules are required for reading the accessed data.
PROEMION Real-Time can quickly process and clearly illustrate "Dashboard" data received via GSM / UMTS bridging. Results are individually configurable, no specific programming skills are required.

Dashboard Software

Visualization individually configurable for:
- cockpit instruments
- circular displays
- bar graphs
- single to five-axis representation
- value display
- status indicator
- buttons and switches
- bar and line diagrams

The new "Dashboard":
- is a free enhancement of PROEMION Real-Time
- can be downloaded on www.proemion.de at the login area
- is extremely easy to handle and price-oriented

Please review our range of services and let yourself be convinced by our diverse applications of telematics solutions.

PROEMION Real-Time Package ¬

Our package includes the following components:

CANlink® GSM / UMTS

The CANlink transmits CAN messages to the PROEMION Real-Time Server via GPRS / UMTS and the Internet.

The device includes all required accessories and software, such as the SoftGateway.

CANview® USB (optional)

The CANview USB is connected to the PC's USB interface and converts all received messages to local CAN, so that the information transmitted to your existing CAN diagnostics device is equal to the source CAN messages.

Security Token

The Token generates authentication data for online identification when accessing the vehicle or machine via a direct Real-Time connection.

PROEMION Real-Time Server

The PROEMION Real-Time Server is for communication handling and message routing.

SoftGateway

This software allows for authentication and connection establishment. Further, it receives CAN data from the PROEMION Real-Time Server and sends it to the local CAN via the CANview USB.

New Dashboard Feature

The "Dashboard" desktop application displays data in real-time.

Cockpit instrument representation is individually configurable.

PROEMION
Telematics Cloud

DE

PROEMION GMBH
Headquarters

Donaustr. 14
36043 Fulda, Germany
Phone +49 661 9490-600
Fax +49 661 9490-666
info@proemion.com
www.proemion.com

US

PROEMION CORP.
US Subsidiary

711 E. Monument Ave., Suite 310
Dayton, Ohio 45402-1490, USA
Phone +1 937 558-2211
Fax +1 937 641-8787
Toll-Free +1 877 RMCAN-US
info@proemion.com
www.proemion.com

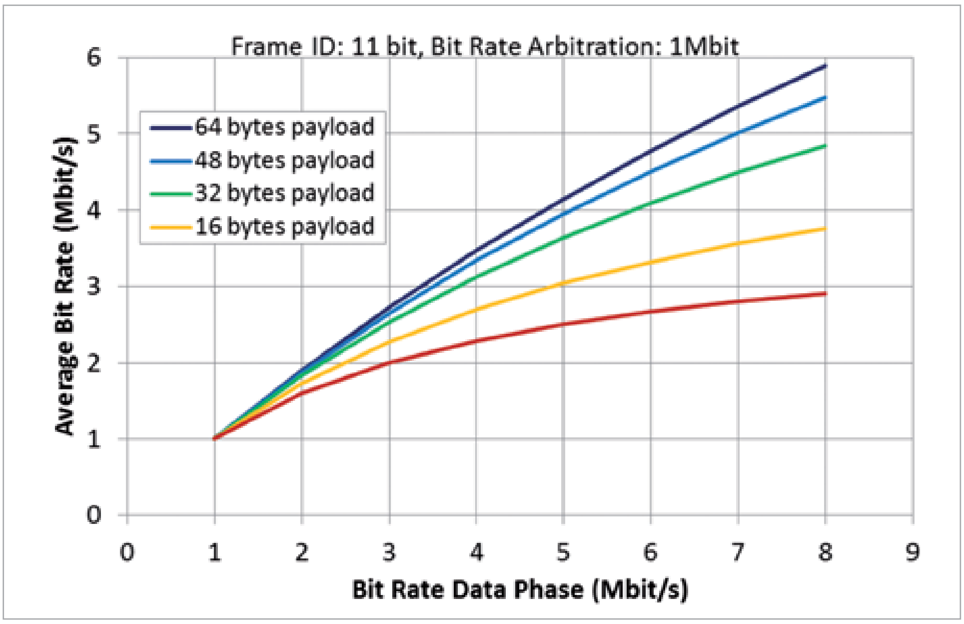


Figure 2: The average CAN FD bit-rate benefits from payloads of up to 64 bytes

Fast software download

According to Moore's Law, the complexity of integrated circuits doubles every 12 months. As stated by Intel executive David House, the performance doubles in a period of 18 months. Similar numbers apply for the overall system complexity and software size. This has already led to the problem that complete software downloads via the on-board diagnostic (OBDII) port to the vehicle ECUs take several hours.

According to General Motors [3] (similar numbers apply for other OEMs as well), the CAN-based OBDII port is used with a nominal bit-rate of 500 kbit/s. To have the maximum net bit-rate, transmissions are supposed to have 8 bytes of data. Thus the time to transmit each frame is 1021 μs.

With CAN FD, the nominal bit-rate is kept at 500 kbit/s, but a data bit-rate of 2 Mbit/s is used. In addition, frames are transmitted with 32 bytes of payload. Increased bit-rate and payload length leads to a reduction in transmission time to 229 μs (see Figure 3). Thus, a four times higher net bandwidth can be achieved solely on the protocol layer. Further speed increases are gained due to the reduced overhead of the transport protocol. A transport protocol usually requires 1 byte for PID (Packet ID), and the 7 bytes of DAQ (data acquisition message), thus resulting in an 88-% net rate. With CAN FD, up to 63-bytes DAQs are possible, which results in a 98-% net rate.

Time-synchronous data transmission for one motion controller

Real-time applications require a reliable time behavior. Mapped to network ▷

	CAN	CAN FD
Bitrate	Nominal: 500 kBit/s	Nominal: 500 kBit/s Data (FD): 2 MBit/s
CAN payload	8 Byte (~15% stuff bits)	32 Byte (~15% stuff bits)
Time to transmit	1021 µs	229 µs

Figure 3: With CAN FD about four times higher net bandwidth is realistic

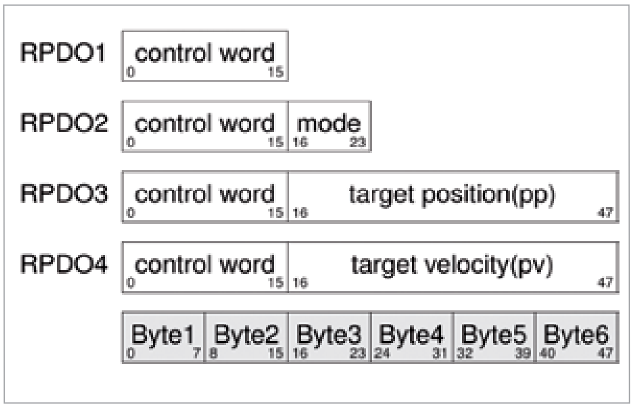


Figure 4: Four PDOs are required to position a motion controller with classic CAN

Tools for CAN FD

Etas already provides tools for CAN FD. During the CAN FD Tech Day in Detroit, modified versions of the FPGA-based ES593-D device and Busmaster were presented. The ES593-D is a member of the CAN FD-capable ES59x ECU and bus access module series also including ES592 and ES595. The ES910 rapid prototyping module supports CAN FD as well. The scalable ES8xx system with a power plate on the bottom and several modules stacked on the top, is scheduled for release in Q2/2014. The available modules interconnected via a high-speed communication network with low latency will include the ES850 analog input module, the ES820 computing module, and the ES890 ECU and bus interface module. The latter will feature CAN, CAN FD, Flexray, ECU access, and connectivity to other company's legacy hardware.
Busmaster 1.7.0 free-to-use open-source solution for network analysis and simulation supports CAN FD. It handles the second bit-rate and frames with up to 64 bytes, each in the message window, and the node simulation. The tool is available since November 2012 and can be downloaded at http://rbei-etas.github.com/busmaster. Inca is a CAN FD-capable tool for measurement, calibration, and diagnostics. The support will be officially released with the market introduction of the ES890. As of today, the configuration formats and transport protocols are not yet ready for CAN FD. Further standardization in ASAM, ISO, and SAE is necessary to take full advantage of CAN FD.

References
[1] Vector Congress, November 2012, Stuttgart, Germany, CAN FD – CAN with flexible data rate, Thomas Lindenkreuz, Robert Bosch
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[3] CAN FD Tech Day in Detroit, USA, October 2012, CAN FD requirements from the OEM point of view, Natalie Wienckowski, General Motors
[4] International CAN Conference in Hambach Castle, Germany, March 2012, Using CAN with flexible data rate in CANopen systems, Heinz-Jürgen Oertel, Port
[5] CAN FD Tech Day in Detroit, USA, October 2012, Safe-guarding of CAN FD for applications in trucks, Marc Schreiner, Daimler AG

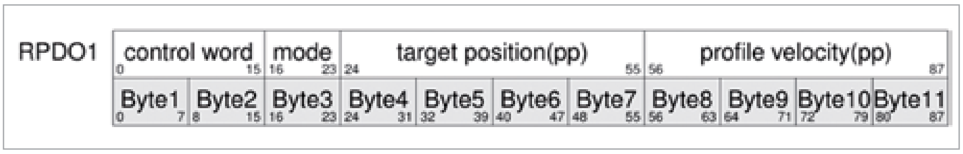

Figure 5: With CAN FD, one message is sufficient to position a motion controller

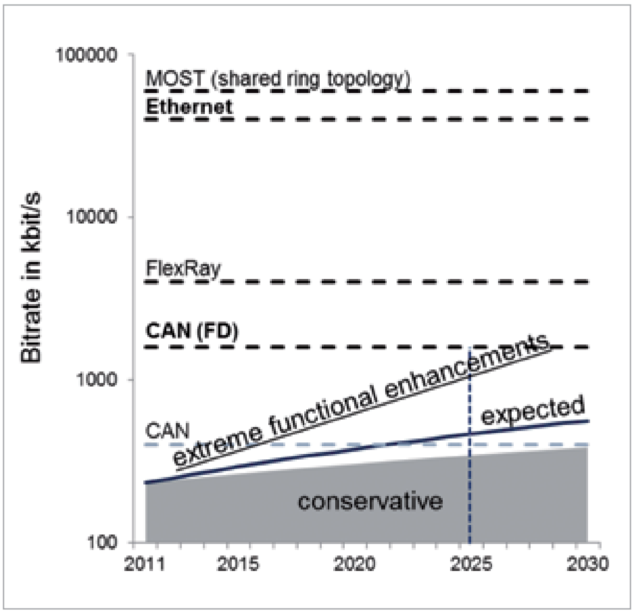

Figure 6: Bit-rate requirements growth estimation for electrical vehicles

technologies, this requirement results in a time-synchronous transmission of information. Due to the fact that CAN is limited to a data field size of 8 bytes, more information has to be transmitted in subsequent messages. To have a reliable time behavior, it has to be ensured that there is no delay or interruption of the transmission due to frames with higher priority. An example for such application is a robot arm [4]. Each axle in this arm is equipped with a motion controller implementing the CANopen device profile for drives and motion control (CiA 402). For each motion controller (axle) four PDOs (process data objects) have to be transmitted with a total of 23 bytes (see Figure 4 in [4]). With the increased CAN FD data field size, there is only one CAN FD frame necessary to position one motion controller. Without further measures, a time-synchronous transmission of information is ensured. In addition, the total number of bytes required for the complete transmission is reduced to 11 bytes, which is a 50-% increase in efficiency.

Higher bandwidth for electric vehicles

Among the CAN-based systems in a vehicle, the powertrain CAN has the highest average utilization. This is mainly due to the communication between the motor control unit and the transmission control unit. Commonly it is used with 500 kbit/s and has a utilization of 50 %.

Especially when it comes to electric/hybrid vehicles, new powertrain concepts demand a much higher bit-rate and utilization. Motor control unit and transmission control unit will be replaced by a vehicle control unit, DC/DC inverter control unit, battery control unit, charger control unit, and range extender control unit. Estimations show that by 2025, the expected required bit-rate will exceed the abilities of CAN and require at least CAN FD (see Figure 6 in [1]). Thus CAN FD is fit for the next generation of powertrain requirements.

Let's assume all frames are transmitted with 8 bytes. Due to the control information in the frame header and trailer, and the additional stuff bits, the data consumes between 40 % and 58 % of the total frame. Using CAN FD and data frames with 32 bytes, the efficiency can be improved to between 64 % and 84 %. In addition, if the nominal bit-rate stays at 500 kbit/s, and a data bit-rate of 4 Mbit/s is introduced, the combined average bit-rate is approximately 1,41 Mbit/s. Both actions result in a reduction of network utilization from 50 % to 11 %. There is no need to add further CAN networks to handle the utilization problem, but further ECUs can be added to existing CAN networks.

Accelerated communication on long CAN lines

Articulated busses feature a CAN network with a length of approximately 20 m. Trucks have a frame length of approximately 9 m. The electronics architecture of trucks and busses is standardized in the SAE J1939 specification. Part 11 and 14 both define the physical layers with a bit-rate of 250 kbit/s and a maximum bus length of 40 m. In the last years, several systems e.g. such ADAS systems (advanced driver assistance systems) as lane departure warning, bird-eye view, and brake assist, migrated from the passenger car segment into the truck and trailer market. This trend demands higher bandwidth than J1939 offers today. J1939-14 was

	SAE J1939-11	SAE J1939-15	SAE J1939-14
Issued	2006-09	2008-08	2011-10
Bit rate	250 kBit/s	250 kBit/s	500 kBit/s
Bus length (L)	40 m	40 m	56.4 m
Stub length (S)	1 m	3 m	1.67 m
Nodes (n)	10	30	30

Figure 7: The nominal bit-rate of J1939 is 250 kbit/s. The introduction of CAN FD with a 4-Mbit/s data bit-rate would lead to an average bit-rate of 810 kbit/s.

Figure 8: The ES59x and ES9xx series are prepared for CAN FD

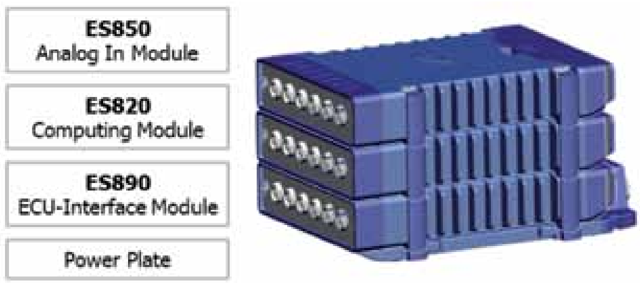

Figure 9: ES8xx series with the ES890 ECU and bus interface module

standardized to have a bit-rate of 500 kbit/s and increased the maximum bus length to 56,4 m. With CAN FD it is possible to keep the nominal bit-rate constant, and to increase the data bit-rate independent of the cable length. If CAN FD is used with a nominal bit-rate of 250 kbit/s and a data bit-rate of 4 Mbit/s, the average combined bit-rate would be 810 kbit/s. Thus, the transfer capacity is increased to 324 %. ◀