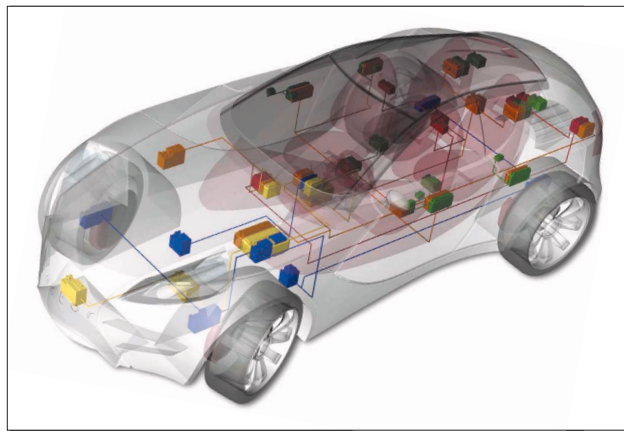


# Status quo and future of ECU communication in automobiles

by Eugen Mayer, Vector Informatik

*To couple the systems in a car, various bus systems have established themselves. In the future, it may be that FlexRay will gain additional significance since it is able to aid time- and security-critical applications as well as data-intensive applications. Thanks to the increasing number of intelligent sensors and actuators, LIN might also play a more significant role in the future.*



■ The noticeable increase in driving comfort and increased driver safety are important competitive factors in the automobile market. The networking of electronic control units is playing an ever more important role for both goals. In order to reduce the cabling effort and also the costs, the weight and the need for space that come with increasing networking, the vehicle manufacturers have long since decided upon serial data transmission. In addition to the serial bus system, CAN, LIN and MOST have established themselves in vehicles within a very short time. At the end of 2006, FlexRay will go into series, a bus system especially for use in time and safety-critical applications.

Figure 1 shows the multitude of different serial bus systems in modern vehicles. The controller area network (CAN), which was standardized internationally in 1994, is without a doubt the most-used serial bus system, which can be used several times even within a single vehicle: a slow CAN bus system for the networking of comfort ECUs with a maximum transmission rate of 125 Kbaud (CAN low-speed) and a fast CAN bus system for networking ECUs for the drive and chassis with a maximum transmission rate of 1 Mbaud (CAN high-speed). LIN (local interconnected network) is used for cost-effective and easy data transmission in the sensor/actuator area. The data rate is limited to just 20 Kbit/s, but this is

completely sufficient for transmission of non-critical sensor and actuator signals.

For real time-critical applications, there is a need for a bus system that is independent of the bus load, and guarantees hard real-time. Real-time-critical systems are often also safety-critical systems. FlexRay is the solution here: with a maximum data rate of 20 Mbit/s and based on a guaranteed equidistant data transmission, FlexRay ensures deterministic time relationships. A second communication channel enables redundant data transmission. If the data on one channel is disturbed, it is still available via the second channel. Infotainment devices such as navigation, radio, and telephone require a relatively high bandwidth since not just control but also video and audio signals are transmitted. Therefore, MOST (media-oriented system transport) is used for multimedia networking in vehicles. MOST makes available a relatively large bandwidth: with a sampling frequency of 48 kHz, approximately 23 Mbit/s, for the transmission of bit streams, and 768 Kbit/s for the transmission of control signals.

In a serial bus system, several electronic components share a common transmission and communication medium. Data is transmitted bit-serially and can be received in principle by all bus participants, also called bus nodes (broadcasting). In contrast to point-to-point connec-

tions, the cabling effort is significantly lower. This reduces the costs, the need for space and the weight, in addition the reliability is higher and the projection clearer. In connection with the serial data transmission, amongst other things, the following aspects must be taken into consideration: framing (design of messages); addressing (creation of a unique assignment between a frame and the bus nodes; bus access and adherence to time conditions; data backup and error handling, as well as synchronization.

CAN is a democratic message distribution system. Based on the message addressing, each node is available to receive each CAN message (broadcast transmission). A CAN message transmits up to eight data bytes. With the eleven bit-wide message address (identifier), up to 2048 different CAN messages can be specified. Each CAN node has the right, if necessary, to access the CAN bus in order to transmit a CAN message. So that ongoing message transmission is not interrupted by a CAN node that wants to send, all CAN nodes that want to send monitor the bus. Only if the CAN bus is free can a CAN node access it. In order to avoid collisions during simultaneous bus accesses, each CAN message exhibits a unique priority that is coupled to the identifier: the smaller the identifier, the higher the priority of the message (figure 2). With this form of bus access, there can be transmission delays. Especially affected are

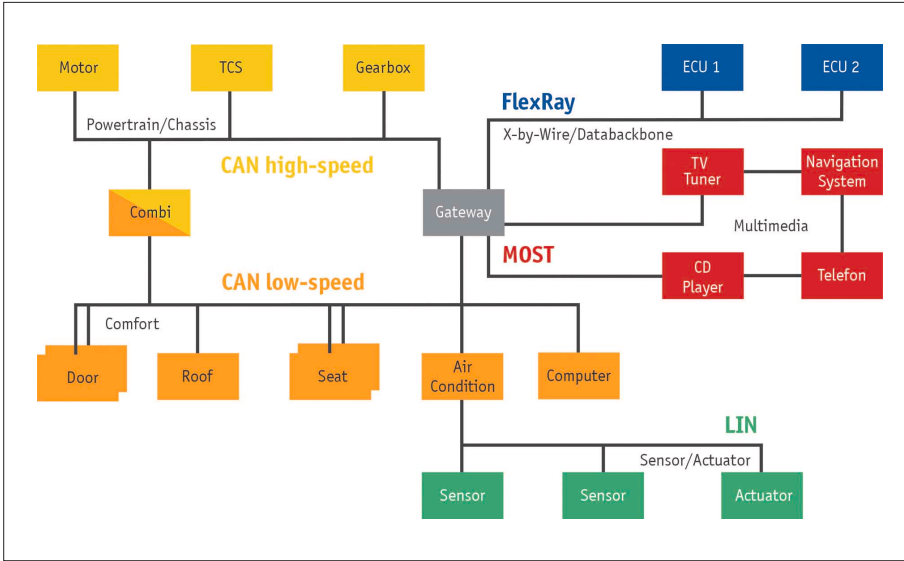


Figure 1. Networking of modern vehicles with serial bus systems

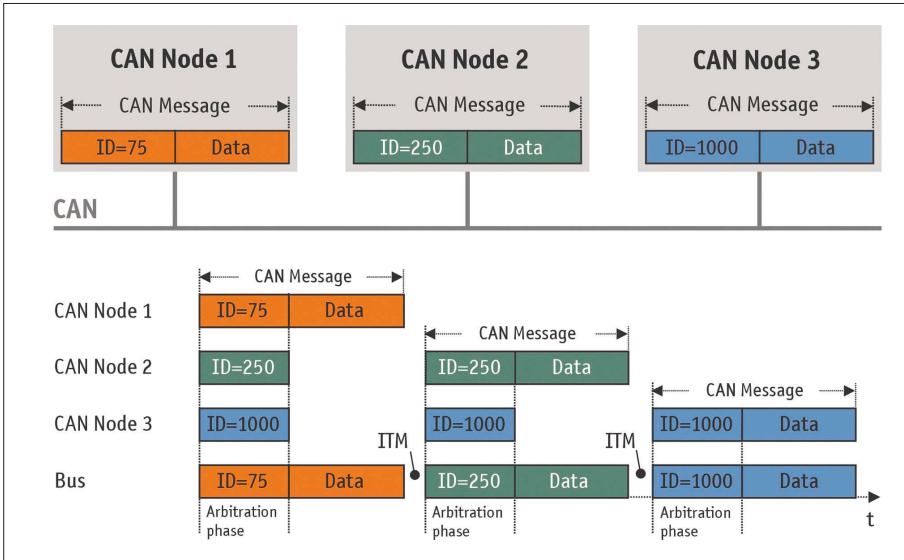


Figure 2. Communication on the CAN network

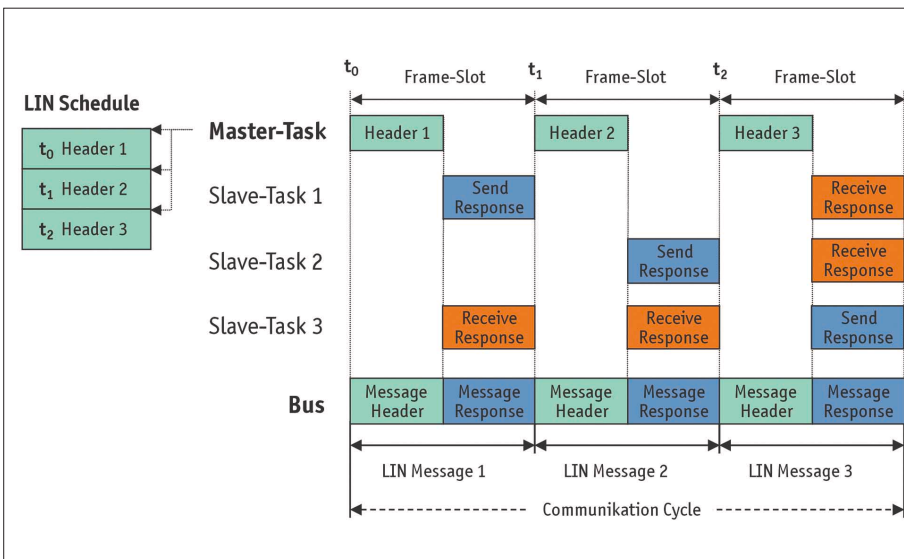


Figure 3. Communication on the LIN network

lower-priority CAN messages. For a particular bus load limit, CAN may no longer guarantee the real-time capability. Thanks to the high adjustable data rates, the required time conditions are nevertheless fulfilled in the drive train and the comfort area. CAN offers extraordinarily high transmission security. An important contribution is made by the difference signal transmission and the cooperation of five error detection mechanisms (among others bit monitoring, form check, cyclic redundancy check), which are handled by the CAN controllers.

With the requirement for a cost-effective communication system for use in the sensor/actuator area, LIN has been used in vehicles as a so-called “sub bus” since 2000. The LIN communication occurs without communication controller and quartz. The data transmission occurs via a single line (single wire). In order to fulfil the interference resistance requirements typical of vehicles, the transmission levels correspond to the battery voltage. But this also increases the interference radiation. Therefore, the transmission rate in a LIN cluster is limited to 20 Kbit/s.

As master-slave architecture, LIN communication is deterministic. Based on a well-defined timetable, one master controls the entire communication in a LIN cluster (figure 3). As soon as a send time point has been reached, the master places a token provided with an identifier on the LIN bus. A LIN slave addressed by the token transmits the corresponding response after the token; this response can consist of up to eight data bytes. The LIN message consisting of token (message header) and response (message response) is available to every LIN node for reception based on the message addressing. Based on the six-bit-wide identifier, up to 64 LIN messages can be specified. In contrast to CAN, LIN is a centrally-controlled message distribution system.

The LIN node contains cost-effective pulse generators which may have a frequency tolerance of up to 15%, a LIN message always begins with the so-called sync break. With its help, all LIN slaves synchronize themselves. The data integrity is checked using parity bits in the message header and a checksum transmitted in the message response. In distinction to CAN, the entire data backup is incumbent upon the software developer because this is not implemented in the hardware.

FlexRay was developed especially for time- and safety-critical applications in vehicles. Therefore, FlexRay uses both a comparatively high data rate (maximum 20 Mbit/s) and also a deterministic and secure data transmission. In addition to deterministic, in a reserved time span, a dynamic transmission is also possible. The real-time capability is guaranteed by a pre-

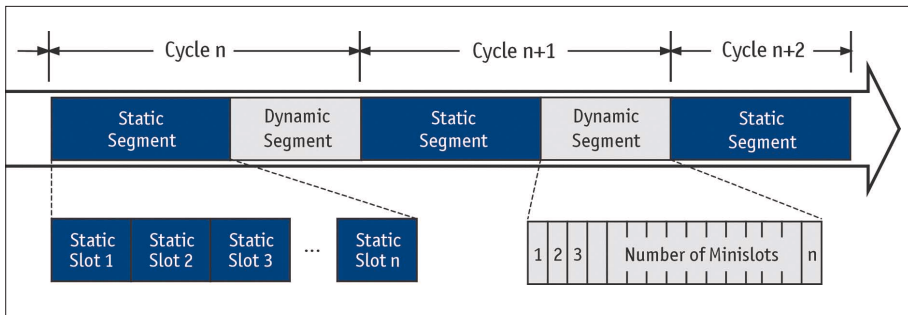


Figure 4. Communication on a FlexRay network

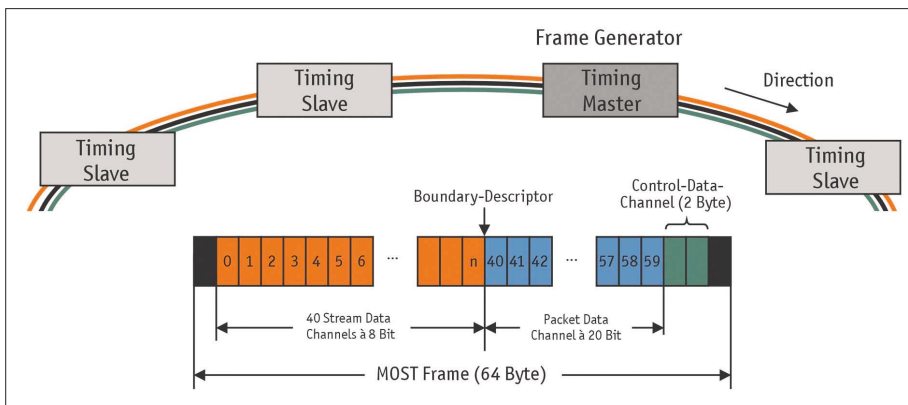


Figure 5. MOST frame transmission with a boundary descriptor value of 10 quadlets

	CAN	LIN	FlexRay
<b>Architecture</b>	Multi-master	Master-slave	Multi-master
<b>Time behaviour</b>	Not deterministic	Deterministic	Deterministic
<b>Bandwidth</b>	1 MBit/sec	20 KBit/sec	20 MBit/sec
<b>Bus access</b>	at random and priority-controlled	Controlled by schedule	Controlled by schedule
<b>addressing</b>	Messages	Messages	Messages
<b>Use bytes per frame</b>	8	8	254
<b>Medium</b>	Two-wire line	Single-wire line	Two-wire line, fiber optic line
<b>Topology</b>	Line, star	Line	Line, star

Table 1. CAN, LIN, and FlexRay in comparison

cisely defined time-flow. The entire communication is organized into communication cycles. In turn, these are subdivided into a static and dynamic communication segment (figure 4).

The static communication segment transmits messages synchronously: the sending times are specified and the messages are transmitted in pre-defined time slots (static slots). Thus deterministic time behaviour is guaranteed. Real-time-relevant messages are therefore preferably transmitted in the static segment. The dynam-

ic communication segment is available for the dynamic message transmission. Here the so-called mini-slottting procedure regulates the bus access in order to avoid collisions. The dynamic segment is especially suited for the transmission of data with low real-time requirements.

For the definition of the communication cycle, the system designer has every freedom. A purely static or dynamic operation is also possible. This flexibility opens up a broad spectrum of applications in vehicles for FlexRay. Further-

more, FlexRay is also favored by vehicle manufacturers based on a simplified system integration. The FlexRay network is a combinable communication network due to the time-controlled communication: the insertion or removal of FlexRay nodes has no effect on the temporal behaviour of the overall system. The transmission security is ensured even across the message format with the help of a difference signal transmission and the multi-level application of the cyclic redundancy check. Bus monitors guarantee that the FlexRay nodes can only send to the time slots permitted for them. High error security is especially created with the help of a redundant communication channel. However, the second channel can also be used to increase the bandwidth. A communication channel has a bandwidth of 10 Mbit/s. In the extreme case, FlexRay offers a bandwidth of up to 20 Mbit/s.

MOST is distinguished from the serial bus systems CAN, LIN, and FlexRay in that – in addition to control signals – bit streams (audio and video signals) are also transmitted. For bit stream transmission (synchronous data transmission), MOST makes available up to 60 communication channels at 384 Kbit/s, which can be allocated via the control channel (768 Kbit/s). Depending on the application, a number of communication channels can be combined via the boundary descriptor into the packet data channel. In this packet data channel, up to 1024 byte large data packets can be transmitted asynchronously.

One node in maximum 64 nodes including a ring coupled via optical fibers takes over the task of the timing master. This ensures that MOST frames are transmitted cyclically from node to node. The time cycle generally corresponds to the sampling frequency of a CD (44.1 kHz) or a DVD (48 kHz). All nodes connected in the MOST ring derive the pulse from the arriving MOST frames and are therefore timing slaves. The MOST frame, which consists of 60 communication channels with 8 bits and one control channel with 16 bits, represents a data container. With the help of bit streams, packet data and control signals are transmitted with reference to channel (figure 5). In addition to the timing master in the MOST ring, there is also another master: the system master. This controls the communication system with the help of MOST commands, among other things the bit streaming between a data source and a data sink. The MOST commands are transmitted with the help of MOST control messages on the control channel.

For networking using CAN, LIN, FlexRay, and MOST, Vector supports the vehicle manufacturers and suppliers with a comprehensive tool-chain and software components. ■