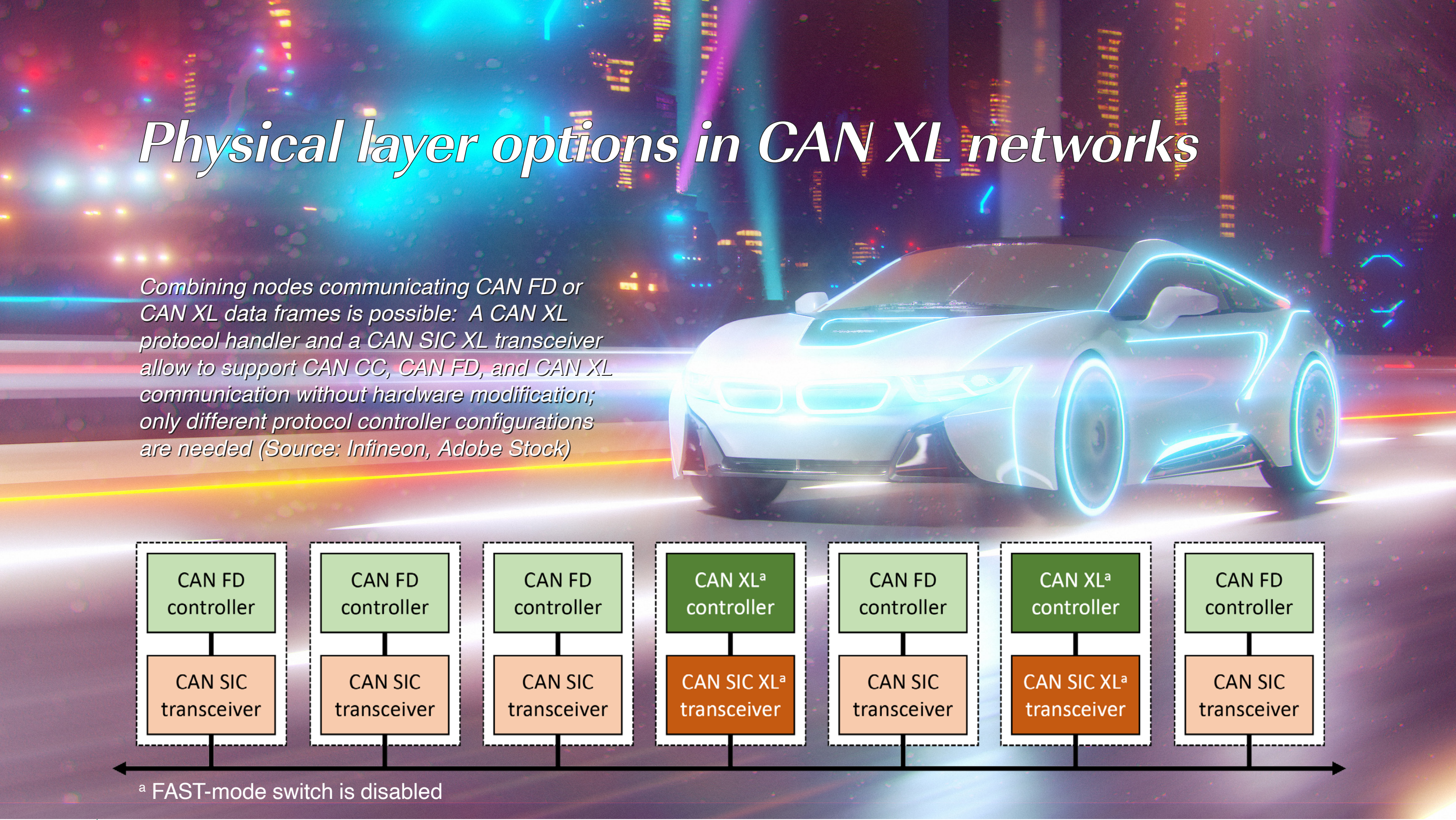
Physical layer options in CAN XL networks



Combining nodes communicating CAN FD or CAN XL data frames is possible: A CAN XL protocol handler and a CAN SIC XL transceiver allow to support CAN CC, CAN FD, and CAN XL communication without hardware modification; only different protocol controller configurations are needed (Source: Infineon, Adobe Stock)

At the beginning of the CAN story, 1 Mbit/s was the highest bit rate. Nowadays, you can achieve up to 20 Mbit/s in the data phase of a CAN XL data frame, when using CAN SIC XL transceivers and enabling the FAST mode. With one CAN node using a CAN XL protocol controller and a CAN SIC XL transceiver, you can realize CAN CC, CAN FD, and CAN XL communication by means of different configurations.

An important advantage of CAN communication is that the CAN physical layer supports multi-drop networks. All nodes on the network receive the CAN frames at the same time. No switches are needed and there is no propagation delay between the different nodes. To organize such kind of communication, especially at the beginning, an arbitration phase is needed. In the arbitration phase all nodes transmit a logical "1" or a logical "0" on the network. To make this possible without damaging nodes or transmit undefined signal levels on the network, only the "0" is actively transmitted on the network as a dominant signal, while a "1" is passively generated by the termination resistors and is called recessive level. In Figure 1, the transmitter-output behavior is shown. The transmitter is switching between high impedance to allow recessive level on the network and low impedance to generate a dominant level. The recessive-to-dominant transition is controlled by the transmitter, while during the dominant-to-recessive transition, the maximum possible slew rate is limited only by the transmitter. This transition is mostly controlled by the wiring harness and the termination resistors. The permanently changing transmitter output impedance during the transmission of dominant and recessive signals causes a ringing on the network. This ringing limits the maximum possible bit rate in CAN networks.

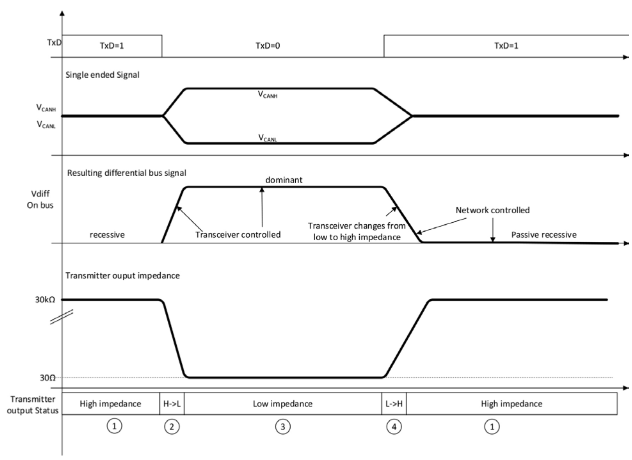


Figure 1: CAN FD transceiver impedance (Source: Infineon)

To achieve higher bit rates, a modification of the transmitter concept has been needed. With the integration of the SIC (signal improvement capability) transmitter, a first step has been done. In Figure 2 the SIC transmitter-output impedance behavior is shown. The dominant-to-recessive phase is now controlled by the transmitter, too. The output impedance changes now from low impedance in dominant phase to medium impedance of 100 Ohm for ▷

maximum 500 ns. This phase is called active-recessive phase. After the active-recessive phase, the transmitter-output impedance changes from medium to high impedance, in order to allow collisions on the network. This phase is called passive-recessive phase. The 100-Ohm impedance in the SIC phase has been chosen to match the transmitter impedance with the typical CAN twisted-pair wire impedance, which is 100 Ohm.

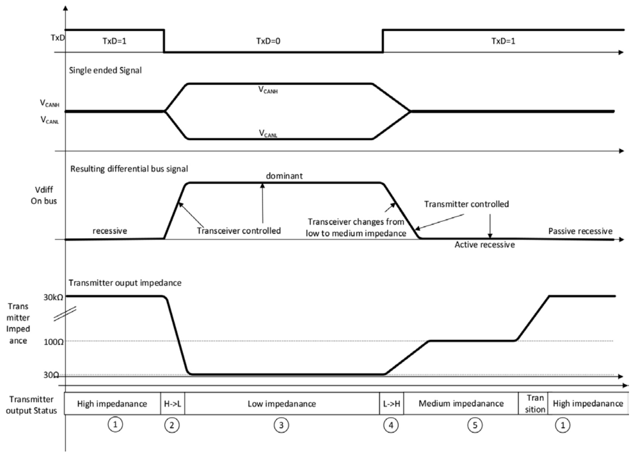


Figure 2: CAN SIC transceiver output impedance characteristic (Source: Infineon)

This modification improves the reliability of existing CAN FD networks and allows bit rates up to 8 Mbit/s. To achieve bit rates above 8 Mbit/s with CAN XL, a new transmitter concept has been needed. In the arbitration phase, the CAN SIC transmitter concept has been chosen and is called SIC mode and in the data phase the push-pull transmitter concept has been chosen, to achieve bit rates up to 20 Mbit/s. This mode of the transceiver is called FAST mode. During the ADS (arbitration to data sequence) phase of the CAN XL protocol, the transceiver changes from the SIC mode to the FAST mode. The mode change is controlled by the CAN XL protocol controller via the TxD pin. The impedance in the FAST mode is, as well as in active-recessive SIC mode, 100 Ohm. But due to the alternating waveforms, the symmetry of the transmitted bits is better than in the SIC mode and allows bit rates up to 20 Mbit/s.

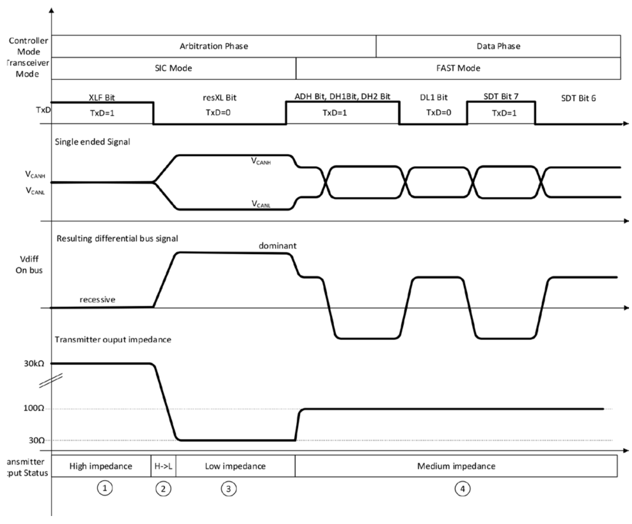


Figure 3: Transmitter impedance characteristic during the SIC to FAST mode transition (Source: Infineon)

In Figure 3, the SIC XL transmitter impedance characteristic during the SIC mode to FAST mode transition and in the FAST mode is shown. The transition starts with a change from dominant level to level_0 and afterwards to level_1. The change from dominant to level_0 is done to get the same voltage swing like in the FAST mode. Otherwise, the ringing due to the higher voltage swing must be analyzed in the transition phase separately. In Figure 4, the mode transition from the FAST mode to SIC mode at the end of the data phase is shown. During the complete FAST mode phase, which is identical with the data phase, the impedance is constant at 100 Ohm and matches with the wire impedance.

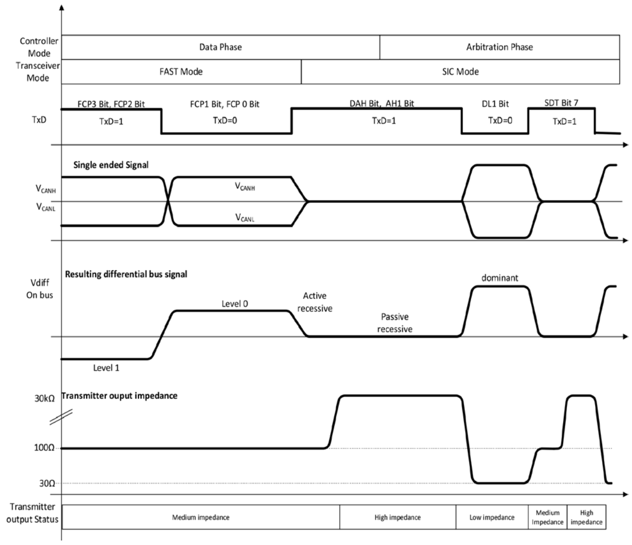


Figure 4: Transmitter impedance characteristic during the FAST to SIC mode transition (Source: Infineon)

The mode change from the SIC mode to FAST mode is controlled by the CAN XL controller via the TxD pin. During the arbitration phase the TxD signals are the same like for all other kinds of transceivers. TxD-high controls recessive level on the network and TxD-low controls the dominant level on the network. In the FAST mode, the controller transmits PWM-coded (pulse-width modulation) symbols to the transceiver. The length of the PWM symbols can vary between 50 ns and 200 ns. If a transceiver detects this PWM symbol, the transceiver changes the mode from SIC to FAST and if no symbols are detected anymore the transceiver switches back to the SIC mode. The duty cycle of the PWM symbol represents the level, which will be transmitted to the network. If the duty cycle is less than 50 %, this represents a logical 0 and level_0 (positive differential signal) is transmitted to the network lines. If the duty cycle is above 50 %, this represents a logical 1 and level_1 (negative differential signal) is transmitted to the network.

Not only the transmitting transceiver is controlled during the data phase with PWM signals, also the receiving transceiver uses the PWM signal to switch into the FAST mode. In the FAST mode, the receiver threshold is set to 0 V instead of 700 mV in the SIC mode. This guarantees that the CAN XL controller and the CAN SIC XL transceiver are always in the same mode. There is no mismatch due to errors, for example. ▷

How to verify CAN XL networks

The most critical scenarios in the CAN XL data frame are:

- the transition from SIC mode to FAST mode,
- a burst of short bits, and
- a short bit after a long level_0 or level_1 phase (in maximum eleven bits according to the stuff-bit rules) with the opposite level.

During the ADH (arbitration to data high) bit, the transmitter switches from dominant to level_0 and afterwards to level_1 and, in parallel, all receiving nodes change the receiver thresholds. This happens by PWM-coded symbols sent from the CAN XL controller to the TxD pin of the transceiver. Before the PWM-coded symbol is detected on the TxD pin, the receiving nodes transmit a short dominant pulse followed by a shortened SIC phase. The requirement is that level_1 is stable before the SDT (service data unit type) field starts. Also, the length of the DL1 (data low) bit is of interest. The transition from the DH2 (data high) bit to the DL1 bit is used for resynchronization of the CAN XL protocol controller after the transition into the data phase. Also, level_0 should be achieved. In the SDT field a "0101" bit pattern has been chosen to analyze the impact of short bits in case of high bit rates.

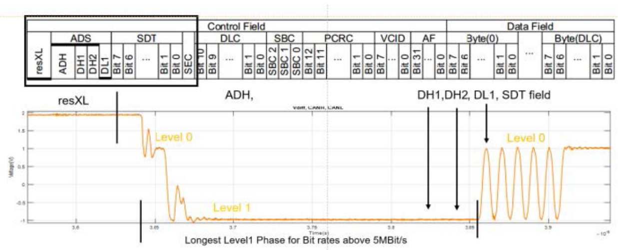


Figure 5: SIC-mode-to-FAST-mode transition during the ADS field (Source: Infineon)

Also, short bits after a high number of bits with the same level is a critical situation. One bit after eleven consecutive level_1 or level_0 bits (highest possible number of consecutive bits) should be used for the investigation. The target is to find out, how the bit length and the level of a short bit behaves after the longest possible phase of the same level in the CAN XL data frame.

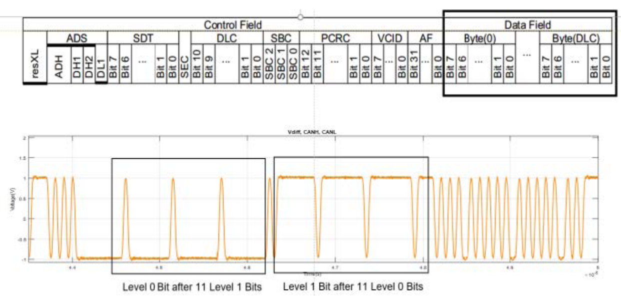


Figure 6: Level_1 or level_0 bit after a long phase (Source: Infineon)

For the verification, the bit-time lengths measured at the +100-mV and -100-mV thresholds should be used. The bit time should be close to the nominal bit time or a multiple of it. For high bit rates, the 0-V threshold can be used, too. Glitches with a length of 20 ns can be ignored.

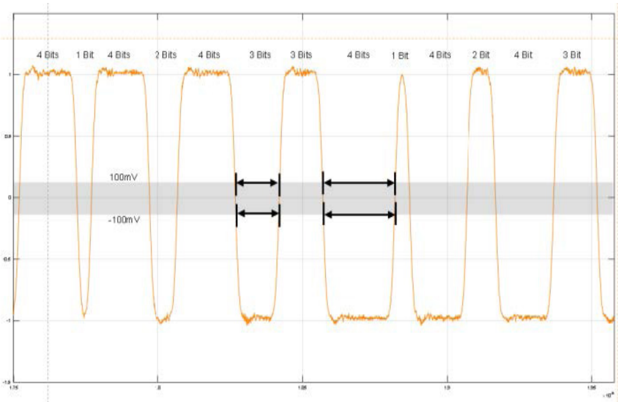


Figure 7: Test criteria timing (Source: Infineon)

Also, the level of short bits should be analyzed and should achieve in minimum 80 % of the nominal level. For an easier verification of CAN XL networks, CAN in Automation (CiA) members develop recommendations for an eye diagram in CAN XL data frames.

Combinations of CAN protocol controllers and CAN SIC XL transceivers

CAN SIC XL transceivers can be used in combination with all variants of the CAN protocol. This allows a lot of opportunities in applications.

The CAN XL protocol handler supports all variants of the CAN protocol:

- CAN CC (classic) with 11-bit and 29-bit identifiers,
- CAN FD protocol with 11-bit and 29-bit identifiers,
- CAN FD light with 11-bit identifiers,
- CAN XL with 11-bit identifiers.

The CAN SIC XL transceiver features:

- the SIC mode (like a SIC transceiver according to ISO 11898-2:2024), and
- the FAST mode (for high bit rates in the CAN XL data phase).

This flexibility allows the combinations of CAN SIC XL transceivers and CAN protocol controllers as shown in Table 1.

Table 1: Combination possibilities of CAN SIC XL transceivers (Source: Infineon)

CAN protocol version	Supported CAN SIC XL transceiver mode		Maximal possible bit rate
	SIC mode	SIC mode and FAST mode	
CAN CC	+	-	500 kbit/s
CAN FD	+	-	up to 8 Mbit/s
CAN XL (FAST mode disabled)	+	-	up to 8 Mbit/s
CAN XL (FAST mode enabled)	-	+	up to 20 Mbit/s

In Table 2, all possible combinations of CAN transceivers, CAN FD transceivers, and CAN SIC (XL) transceivers are given.

The maximum bit rate, given in Table 2, depends on the network topology and might be lower. The maximum possible bit rate can be achieved in a point-to-point network with termination resistors on both sides as well as in many network topologies with very short stubs.

MCU for digital car cockpits

Mediatek has based on Infineon's Traveo CYT4DN microcontroller family a digital cockpit system. The cockpit also comprises an entry-level Dimensity Auto SoC (system-on-chip) solution by Mediatek.

The Traveo MCU dedicated for cockpit designs features up to eight CAN FD interfaces (Source: Infineon)

The trend in the automotive industry is towards digital cockpits, with buttons and controls disappearing from the dashboard and being replaced by advanced displays. This implies also functional safety aspects. Traditionally, high-performance SoCs with hypervisors are used. However, the up-front investment required to get started with such a system is in the seven-figure range, and the license fees for the operating system and hypervisor add to the overall cost of the system, making it economically unattractive for mid- to low-end car models.

Infineon together with Mediatek have developed in co-operation with design house partners a cockpit solution. The Infineon MCU (micro-controller unit) works as a safety companion to the SoC by Mediatek to meet the ASIL-B (automotive safety integrity level) safety target for automotive clusters. The MCU monitors the content rendered by the SoC and takes over with reduced functionality in case of an error, in addition to normal companion functions such as communication with the vehicle network. The MCU features multiple CAN FD (flexible data rate), CXPI (Clock Extension Peripheral Interface), and LIN ports.

"A modern cockpit supports the driver and increases driving comfort for all vehicle occupants. That is why it is important to us that cost-optimized vehicle models can also be equipped with digital solutions. Together with Mediatek and our partners, we are pleased to pave the way for digital cockpits for all vehicles," said Ralf Koedel, working with Infineon. "The Traveo MCU incorporates our low-power flash memory, multiple high-performance analog and digital peripherals and enables the creation of a secure computing platform."

This launched cockpit solution supports a resolution of 1920 x 720 pixels for clusters and the in-vehicle infotainment display. The MCU is designed for automotive systems such as instrument clusters and head-up displays (HUD). It features a 2,5-D graphics engine, sound processing, two Arm Cortex-M7 cores for primary processing at up to 320 MHz and an Arm Cortex-M0+ core for peripheral and safety processing. The family also features a 720p GFX and a unique 327-ball BGA package. Memory options include 4 MiB of VRAM, 6 MiB of flash memory, and 768 KiB of RAM. *hz*

Table 2: Combinations between CAN transceiver types and CAN protocol versions (Source: Infineon)

CAN protocol	CAN transceiver type			Maximal possible bit rate
	CAN transceiver	CAN FD transceiver	CAN SIC (XL) transceiver	
CAN CC	+	-	-	500 kbit/s
	-	+	-	up to 5 Mbit/s
	-	-	+	up to 8 Mbit/s
CAN FD	+	-	-	500 kbit/s
	-	+	-	up to 5 Mbit/s
	-	-	+	up to 8 Mbit/s
CAN XL	+	-	-	500 kbit/s
	-	+	-	up to 5 Mbit/s
	-	-	+	up to 20 Mbit/s

The CAN FD protocol and the CAN XL protocol allow a mixed communication in one network. If CAN FD protocol handler detects a CAN XL data frame, it stops frame detection after the FDF bit and changes into reintegration mode and is waiting until the end of the CAN XL data frame. The CAN XL controller is able to support both frame types. But for both protocols the same arbitration bit-time configuration is needed.

On the physical-layer side, there is the situation that in the CAN SIC XL transceiver FAST mode the differential bus levels might be below the receiver thresholds of CAN FD and CAN SIC transceivers. This has the consequence that from the physical layer point-of-view a reliable mixed protocol communication is only possible, if all nodes are using CAN FD or SIC mode only. The transceiver with the lowest possible bit rate defines the maximum bit rate in the network. An example: Some nodes in the network use CAN FD controllers and CAN FD or CAN SIC transceivers, while other nodes apply CAN XL controllers and CAN SIC XL transceivers. The communication is working properly, if CAN SIC XL transceivers are working in SIC mode only (FAST mode is disabled by configuration). For the arbitration and the data phase, this can be configured in the CAN XL controller. In such a network, CAN SIC transceivers enable bit rates of up to 8 Mbit/s as the maximum possible bit rate for CAN FD and CAN XL communication. The maximum bit rate can be reduced depending on the network topology. Reflections and ringing in the network can reduce the maximum achievable bit rate dramatically. The maximum possible bit rate for each network should be verified via simulation. ◀

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